Die Vegetation der Erde

Sammlung
pflanzengeographischer Monographien

herausgegeben von

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XIV.

The Vegetation of New Zealand

By

L. Cockayne
Ph. D., F. R. S., F. L. S., F. N. Z. Inst.

Leipzig
Wilhelm Engelmann

New York
G. E. Stechert & Co.

1921

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With 2 Maps, 65 Plates and 13 Figures in the Text

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Preface.

Early in the year 1904 I had the honour to receive a letter from Prof. Dr. A. ENGLER inviting me to contribute to the comprehensive "Vegetation der Erde" a volume written in English dealing with the plant-geography of New Zealand. At the same time Prof. ENGLER sent me a synopsis of the proposed work, which he had prepared, and on that, with certain modifications, this book is based.

At that time many wide areas in New Zealand were botanically unexplored, and a great part of the remainder was imperfectly known, consequently it was essential for me to acquire a first-hand knowledge of at least typical examples of the vegetation of each botanical district. This preliminary work was steadily carried on year by year, but it was not completed until June, 1913, at which period the actual writing of the book was begun. By the end of March, 1914, the work was completed, and soon afterwards the manuscript was forwarded to Berlin.

It is no easy matter, even when in close touch with the publisher, to see a scientific work through the press. How much then are the difficulties increased when half the circumference of the Globe separates publisher and author. Nor are these difficulties lessened when the copy for the printer to deal with is in a foreign tongue. But consider the infinitely greater difficulties which arose through the long years of the gigantic world-struggle and the subsequent time of reconstruction!

Much of the book only came into my hands in the form of paged proofs, so little more than verbal corrections could be made. Fortunately this was not the case from page 209 onwards, for of this portion galley proofs were available. These reached me in June, 1920, rather more than six years after the manuscript had left New Zealand, and, thanks to the publisher, I was permitted to make certain important alterations designed to bring the latter part of the work up to the present-day state of knowledge of the vegetation and flora of New Zealand. Not that the other part of the book is greatly deficient in this respect, since much of the theme is the *primitive* plant-covering.

With regard to the classification of the vegetation, with some modifications Warming's system of 1909 is followed. But the system adopted for such a book as this is not of great moment, since, above all else, the aim should be to present as vivid and accurate a picture as possible of the actual vegetation of the country. This surely is the first step in a plant-geographical description of any country. And it is the more necessary in a region, such as New Zealand, possessing a truly virgin vegetation which is rapidly becoming modified, or even destroyed.

As for the biology of the plants the somewhat novel method is adopted of giving detailed statistics regarding the growth-forms of the species and of certain of their vegetative parts. This procedure should be useful for comparative purposes both in the region dealt with and elsewhere. Obviously in deciding certain points, such as relative size or texture of leaves, the personal equation comes in, but where many species are concerned this should not affect the general result.

No attempt is made at completeness. On the contrary, owing partly to the limited space available and partly to the great variety of New Zealand plant communities, the matter is greatly condensed. Many species, especially those which are rare, are not mentioned; it is, after all, the common ones which are of prime importance.

The reader not acquainted with the New Zealand flora has been kept in mind. The leading physiognomic plants are treated at considerable length for each section of the vegetation, while the growth-forms of many species are described when they first appear in the text. Vernacular names are specially avoided.

Since 1914 I have ceased calling the tussock formations of New Zealand "steppe" because they do not fit into the usual plant-geographical conception of that term. I have therefore substituted "tussock-grassland" as a self explanatory name for a distinct type of vegetation. This term appears once or twice in the latter part of the book, but generally "steppe" remains. It must be remembered, then, that the latter is ecologically distinct from true steppe, indeed it has much wider physiological capabilities and can maintain itself intact under a surprising variety of conditions.

The meaning of "epharmonic", as used in the biological chapters, must be explained, since its significance according to my usage is somewhat different to Vesque's definition of the term. In this book, and in my other publications, by "epharmonic variation" is meant a change in its form, or physiological behaviour, beneficial to an organism evoked by the operation of some environmental stimulus. Such a change may be called an epharmonic adaptation as distinguished from such adaptations as cannot be traced to any direct action of the environment.

Apart from those mentioned in the text with regard to photographs, or special information, which they have generously supplied, many botanists and others have given valuable and much-appreciated assistance with regard to this book. To name all would extend this preface far beyond its alloted space, to give merely a partial list would be invidious. Therefore, I thank most sincerely one and all.

I must, however, express my gratitude to Prof. Dr. L. DIELS who has devoted much valuable time to seeing the book through the press. Nor can I neglect thanking Prof. Dr. A. ENGLER for having allowed me the great privilege of contributing to this famous series of monographs of which he and Prof. Dr. O. DRUDE are the distinguished Editors.

Ngaio, Wellington, New Zealand,
January 15th, 1921.

L. Cockayne.

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The Vegetation of New Zealand

Introduction.

History of the Botanical Investigation of New Zealand.

Chapter I. Botanical Exploration and Research.

1. The Period of Voyages of Discovery in the South Pacific, and of Investigations by Botanists from abroad.

a. The Voyages of Captain Cook.

Leaving out of the question the remarkable knowledge of plants acquired by the Maoris, New Zealand botany commences with the landing of Sir JOSEPH BANKS and Dr. SOLANDER at Poverty Bay on Oct. 8th, 1769, from COOK's famous ship, the Endeavour. The natives were hostile, but notwithstanding, 40 species of plants were collected. COOK remained in New Zealand waters until March 31st, 1770. Collecting was confined to a few places on the North Island coast from Poverty Bay to the Bay of Islands, and in the South Island to Queen Charlotte Sound and Admiralty Bay. Altogether some 360 species of vascular plants were gathered, the bulk coming from Tolaga Bay (160 spp.) and Queen Charlotte Sound (220 spp.). Since botanizing was, of necessity, restricted to the vicinity of the shore, the above figures speak eloquently of the zealous industry of BANKS and SOLANDER.

On the return of the expedition in 1771, BANKS, at his own expense, caused 200 fine folio copper plate engravings of the plants to be prepared accompanied by MS. descriptions of the species from the hand of SOLANDER. All was complete, but although the work has lain these long years in the British Museum, it is still unpublished!

COOK set sail on his second voyage on April 9th, 1772. He was accompanied by Dr. J. R. FORSTER and G. FORSTER, the son, as naturalists, parliament having voted £4000 for their expenses. At the Cape of Good Hope, A. SPARMANN was engaged as assistant naturalist. On March 26th, 1773, COOK put into Dusky Sound, remaining until May 1st, during which period the first investigation of the actual South Island flora[1]) was made. May 18th to June 7th was spent in Queen Charlotte Sound. The total number of vascular

1) That of Queen Charlotte Sound is almost identical with the southern North Island flora.

plants collected was 190, a poor result considering the great opportunities for collecting. The botanists never ascended any of the mountains at Dusky Sound, and their rich alpine flora remained unknown, but for two or three specimens probably collected by some of COOK's officers who partially climbed one of the mountains[1]). Twelve months after their return, the FORSTERS conjointly issued their "Characteres Genera Plantarum", in which, with other genera, 31 belonging to New Zealand are described and figured. In 1786 G. FORSTER published his "Florulae Insularum Australium Prodromus", 170 of the species mentioned therein being from New Zealand. The book is of little scientific value, the descriptions being brief and inadequate. SPARMANN appears to have drawn up the diagnoses though his name does not appear.

Botanically, COOK's third voyage was of little moment. The surgeon of his ship, W. ANDERSON, however, wrote an excellent, but very short account of the vegetation of Queen Charlotte Sound which may be considered the first contribution to New Zealand botanical ecology.

b. From Vancouver's Voyage (1791) *to the Publication of the "Flora Antarctica"* (1847).

In 1791, Captain VANCOUVER, on his way to N. W. North America, put in to Dusky Sound for nearly 3 weeks. A. MENZIES, the surgeon, collected ferns, mosses and liverworts most assiduously. The greater part of his specimens were described and beautifully figured by Sir W. J. HOOKER in the "Musci Exotici" (1818—20) and the "Icones Filicum".

It was not until 1824 that further investigations were made regarding New Zealand botany, when from the French exploring corvette, "Coquille", Lieut. D'URVILLE and A. LESSON made a collection of plants at the Bay of Islands. The colonization of New South Wales had for some time past made itself felt. Whaling and sealing were pursued with vigour on the New Zealand coast; missions had been established since 1814, and settlement in the north was gradually extending. C. FRASER of the Sydney Botanic Garden, in 1825, collected a few plants at the Bay of Islands, and probably he had previously received one or two species from Macquarie Island.

In 1826, ALLAN CUNNINGHAM, His Majesty's Botanist at Port Jackson, spent four months in botanizing from the Bay of Islands to Hokianga and in the neighbourhood of Whangaroa. Aided by natives and missionaries, he did valuable work, collecting 300 species, many of them new, together with ample duplicates. The following year, D'URVILLE again visited New Zealand, this time as commander of the "Astrolabe". He was accompanied, as before, by LESSON. Collections were made at various localities on the north coast of the South Island, and at a few places in the North Island from Tolaga Bay to the Bay of Islands. The botanical results were published in 1832 by

1) It must be remembered that botanical exploration at any point in the Fiord district is most difficult owing to the excessively wet climate and the extremely rugged, steep and densely forest-clad mountains. In fact the greater part is still unbotanized.

A. RICHARD in his "Essai d'une Flore de la Nouvelle Zélande", which included also the previous French collections and those of the FORSTERS. This excellent publication, even yet of moment, is the first dealing with the flora as a whole. The 380 species include 211 spermophytes, 51 pteridophytes and 118 lower cryptogams. R. CUNNINGHAM, brother of ALLAN, and Superintendent of the Sydney gardens, made extensive collections during 5 months of 1833 spent near Whangaroa, the Bay of Islands and Hokianga. The material collected by himself and his brother forms the basis of a series of papers by A. CUNNINGHAM published in the "Companion to the Botanical Magazine", vol. 2, and continued in the "Annals and Magazine of Natural History" under the title "Florae Insularum Novae Zelandiae Precursor". This important work contains descriptions of nearly all the then known species and includes 639, of which 394 are spermophytes, 95 pteridophytes and 150 lower cryptogams, an increase of 259 species since RICHARD's work. In 1839, Mr. J. C. BIDWILL visited New Zealand, penetrating to the centre of the North Island and ascending Mt. Ngauruhoe, in the neighbourhood of which he discovered many typical alpine plants. Later on, he revisited the Colony and, in Nelson, added to the knowledge of the alpine flora. From 1840—42 Dr. E. DIEFFENBACH, naturalist to the New Zealand Company, travelled through much of the North Island, ascended Mt. Egmont, and, in the South Island, spent some time on the coast of Marlborough. Considering his excellent opportunities, his collections were scanty. In his "Travels in New Zealand" (1843) there is some scattered information as to the vegetation, and one chapter deals briefly with the flora. He also visited Chatham Island, but only gathered 12 species. The flora of Banks Peninsula was first investigated in 1840—41 by E. RAOUL, surgeon to the "Aube" and "Allier", French corvettes. He discovered many new spermophytes and in 1844 his finely illustrated "Choix de Plantes de la Nouvelle Zélande" appeared in which are enumerated all the then known species.

The years 1839—40 mark a most important phase in the history of New Zealand botany, in the searching examination of the Lord Auckland and Campbell Islands by the botanists of the French and English Antarctic expeditions. The former, under Admiral D'URVILLE, anchored in Port Ross from the 11th to the 12th of March 1840. Botanical collections were made by the naturalists, HOMBRON and JACQUINOT, and the admiral himself. The results were published at intervals from 1845—54 as part of a splendid work, "Voyage au Pole sud et dans l'Oceanie sur les Corvettes "l'Astrolabe" et "la Zélée" pendant les années 1837 à 1840" [1]).

The English expedition, under Sir JAMES ROSS, spent from Nov. 20th to Dec. 13th at the northern end of the Lord Auckland Group, and from Dec. 13th to Dec. 17th 1840 on Campbell Island. Sir JOSEPH HOOKER was

1) There is a folio volume of admirable plates with the names of the species by HOMBRON and JACQUINOT, and two volumes of descriptions, the one (*Muscineae* and *Thallophyta*) by MONTAGNE, and the other (vascular plants) by DECAISNE.

botanist to the expedition, and, associated with him was Dr. LYALL. It is impossible to speak too highly of HOOKER's untiring industry and skill as a collector, for notwithstanding the subsequent visits of several botanists to these islands, and of one well-equipped expedition, but few additional species have been recorded. HOOKER devoted the first volume of his magnificent "Flora Antarctica" (1847) to the description of this wonderful flora that he had been so largely instrumental in making known. The 400 species dealt with comprise 105 spermophytes, 18 pteridophytes, and 277 lower cryptogams. CHEESEMAN (1909: 392) truly declares the work "A splendid monument of painstaking exploration and research". The American WILKE's expedition visited Lord Auckland Island at about the same time as the French, but its botanical discoveries are of little moment.

2. The Period of Colonial Collectors and Hooker's further Investigations.

a. General.

Although a scattered European population had occupied parts of the northern North Island for some 20 years, it was not till 1839 that regular settlement began, and that one after the other the Provinces were founded. Thenceforth, the history of botanical research is wrapped up with that of the development of the Colony, and for some time its progress depended on that love for Nature which inspired a few enthusiasts to collect the plants near at hand, or even to undertake distant botanical excursions. But there were none in the young Colony that felt equal to describing their discoveries, nor indeed was there means for local publication. Consequently, all sent their collections to Sir JOSEPH HOOKER, and well it is they did so, since he was not only easily the most competent man of his day to deal with them, but the great resources of Kew and the collections of the earlier explorations were at his disposal.

b. From the Coming of Colenso to New Zealand to the Publication of the "Flora Novae-Zelandiae" (1853—55).

The Rev. W. COLENSO came to New Zealand as a missionary in 1834. His earliest collections were made from the North Cape to Whangarei. Between the years 1842 and 1847, he accomplished many arduous journeys on foot through some of the most difficult country in the North Island accompanied only by a few Maoris. The Ruahine Mts., the Volcanic Plateau and the high lands of the East Cape District were perhaps the most important of the many localities visited, since they added many species to the little known alpine flora, while his discoveries as a whole were, according to HOOKER, second only in number to those of Banks and Solander. At about this time, Dr. A. SINCLAIR collected copiously on the east of the North Island, and somewhat later he added, in Nelson, a good many species to the alpine flora.

From 1847—51, Dr. LYALL, surgeon to the "Acheron", then surveying the coast, made important collections chiefly in the S. and S. W. of the South Islands. Though he ascended to more than 900 M. in the Fiord district, he does not esem to have gained the actual alpine belt. Early in the fifties Sir DAVID MONRO commenced his valuable explorations of Marlborough and eastern Nelson, and some of his novelties are recorded in the appendix to the "Flora Novae-Zelandiae". In 1853, the first volume appeared, dealing with the spermophytes, and two years later, the second volume devoted to the cryptogams[1]). CHEESEMAN most truly declares that this work "marked a new era in the botany of New Zealand". The number of species described, 1767, nearly doubled the last enumeration. The work abounds in information valuable for the present-day student of the flora, but more important still is the classical "Introductory Essay" in which there is a philosophical discussion on the limits of species, variation, the affinities and origin of the flora and so on, which for lucidity, marshalling of facts, carefully balanced conclusions, and praiseworthy moderation has never been excelled.

c. From 1855 *to the Publication of the "Handbook" in* 1867.

When the "Flora Novae-Zelandiae" appeared nothing was known of the South Island alpine flora beyond the results of sparse collecting in the extreme northern mountains, nor of that of the lowlands except at distant points along the coast. The years 1855—67 saw this unhappy state of affairs righted thanks especially to the labours of TRAVERS, HAAST, HECTOR and BUCHANAN. Nor would the services of the three latter have been available, but for the founding of Canterbury and Otago in the early fifties, and the establishment of geological surveys by their governments.

W. T. L. TRAVERS explored the Nelson portion of the Southern Alps from 1854—60, making important collections which he sent to Kew. He discovered many new species. Sir JULIUS VON HAAST, although primarily a geologist, made extensive collections of plants during his explorations of wide areas for the most part absolutely unknown. The central chain of the Southern Alps and its neighbourhood were the chief scenes of his labours. His collections and observations threw a flood of light upon the alpine florula, putting it into its true position in the general flora of New Zealand. Sir JAMES HECTOR and Mr. J. BUCHANAN explored the rugged mountains of S. W. OTAGO; HECTOR, amongst other things, accomplishing the great feat of crossing the Southern Alps from E. to W. over a high ice-clad shoulder of Mt. Aspiring. Their collections were of the utmost value, not merely for their many novelties, but because they showed S. W. OTAGO to be a well-marked botanical district[2]). The botany of eastern Otago, from Dunedin to the mouth of the Clutha and

1) The parts relating to the mosses, liverworts, algae, fungi and lichens were written by WILSON, MITTEN, HARVEY, BERKELEY and BABINGTON respectively.

2) The names and boundaries of the botanical provinces and districts as used throughout this book will be found in Part III, Chapter I.

inland to Tuapeka was, in part, made known by Dr. LAUDER LINDSAY of Edinburgh, who spent 4 months at the task in 1861—62. He supplied HOOKER with a set of his plants and afterwards published his "Contributions to New Zealand Botany" (1868). In 1863 Dr. F. VON HOCHSTETTER's classical work on New Zealand appeared. Although mainly geological, it contains much ecological information, including an excellent account of North Island rain-forest. The same year saw the visit of Mr. H. H. TRAVERS, at the instance of his father, to the Chatham Islands. During a four month's stay, he formed that large collection, which entrusted to Sir FERDINAND VON MUELLER, resulted in the publication in 1864 of "Vegetation of the Chatham Islands" in which 129 species of vascular plants are enumerated.

Through the representations of Dr. KNIGHT and others, the New Zealand Government, in 1861, arranged with HOOKER to prepare a flora of the region, on the lines recommended by Sir W. J. HOOKER for a uniform series for the British Colonies. The part dealing with the vascular plants appeared in 1864 as Part I of the "Handbook of the New Zealand Flora", and Part II, dealing with the *Muscineae* etc. together with an appendix recording recent discoveries in 1867. How successful the exertions of the collectors mentioned above had been is shown by the fact that the 850 vascular plants known in 1855 had increased to 1070 in 1867, while data regarding distribution were greatly augmented. That the work was most excellent, HOOKER's name is sufficient guarantee, but that descriptions so full and clear were drawn up, in most cases from dried material, must be a source of wonder and admiration to all using the "Handbook".

3. The Period of Publications by New Zealand botanists.

a. *From the Founding of the New Zealand Institute in* 1867 *to the Publication of Kirk's "Students' Flora" in* 1899.

In 1867 the New Zealand Institute was founded by Act of Parliament which assured it an annual income of £500.[1]) To it were affiliated, in due course, the local scientific societies of the Provinces. There was now ample means of publication for local workers, who alone can undertake those critical studies which demand observations from living plants. Nor were such workers wanting as a glance at the Bibliography of the volume shows. Indeed matter was awaiting publication, and the first volume of the Transactions of the new Society included plant-geographical essays previously written by certain of those collectors who had done such yeoman service for HOOKER, e. g. COLENSO, HECTOR, MONRO, TRAVERS and BUCHANAN. Especially important are HECTOR's principles of plant-distribution in the South Island[2]) and COLENSO's phyto-geographical areas of the North Island[3]), both marking a distinct advance.

1) Notwithstanding the great increase of the Dominion in population and wealth this sum has never been increased.

2) He defines western, central and eastern climatic provinces and 3 vertical belts. The influence of the Divide is appreciated and stress is laid on the continental climate of the centre.

3) Six areas and seven vertical belts.

The progress during this sub-period was very considerable. Year by year, new species of spermophytes were published and, though many are certainly invalid, at a low estimate the number of species allowed in the "Handbook" was increased by one half. Localities, of which the florulas were virtually unknown, were investigated and those but hastily examined were explored afresh, indeed knowledge as to plant-distribution increased fourfold. Floristically, more intensive studies were made of certain critical genera and species. Three works of major importance were published, — "The Indigenous Grasses of New Zealand" (BUCHANAN 1880), "The Forest Flora of New Zealand" (T. KIRK 1889) and "The Students' Flora of New Zealand and the Outlying Islands" (T. KIRK 1899). Of the numerous botanical collectors and authors three stand forth conspicuously: T. KIRK, T. F. CHEESEMAN and D. PETRIE. COLENSO, BUCHANAN, TRAVERS and KNIGHT continued their labours, those of COLENSO ceasing only at his death in 1898, he having been an active worker in the field for at least 60 years. Others of the subperiod who have imprinted their mark on New Zealand botany are: G. M. THOMSON, J. ADAMS, J. B. ARMSTRONG, J. F. ARMSTRONG, T. H. POTTS, A. HAMILTON, R. BROWN, S. BERGGREN, T. N. BECKETT and R. M. LAING.

In order to gain a chronological view of the progress made, the sub-period may be divided into decades, the first terminating with 1877. During this decade lists of species of the following localities were published: Mt. Egmont and Marlborough (BUCHANAN 1869), Great Barrier Island (KIRK 1869), the Thames district (KIRK 1880), the Port Hills and adjacent plain (J. F. ARMSTRONG 1870), the northern district of Auckland (BUCHANAN and KIRK 1870), Auckland Isthmus (KIRK 1871—72), Titirangi district (CHEESEMAN 1872), Hot Lakes district (KIRK 1873), Wellington Province (BUCHANAN 1874), Chatham Islands (BUCHANAN 1875), 45 additions to the Otago Flora (G. M. THOMSON 1877). Lists of introduced plants were drawn up by KIRK, J. F. ARMSTRONG and G. M. THOMSON, respectively, for Auckland (1870), Canterbury (1872) and Otago (1875).

The second decade ends with 1887. The important localities for which lists were published are: Bluff Harbour; 109 additions to the Otago flora and Islands in Hauraki Gulf (KIRK 1878); Okarito to the Franz Josef Glacier, previously unknown (HAMILTON 1879); Mt. Pirongia, previously unknown (CHEESEMAN 1879); Canterbury Province (J. B. ARMSTRONG 1880); Stewart Island[1]) (PETRIE 1881); Nelson Province[2]) (CHEESEMAN 1882); Macquarie Island[3])

1) The flora was unknown, but for 12 seed-plants and a few cryptogams collected by LYALL, and one or two plants gathered by G. M. THOMSON. Only the seed-plants are recorded, 200 species having been collected. The important discovery of typical alpine plants at sea-level was made. G. M. THOMSON accompanied PETRIE.

2) The list is a record of the species collected on journeys made by CHEESEMAN 1878 and 1881. The 675 species of vascular plants recorded speak eloquently to the energy of the author.

3) Virtually unknown prior to Dr. SCOTT's visit. Thirty-nine species are recorded (16 seed-plants, 3 ferns, 8 mosses, 6 lichens, 6 fungi).

(SCOTT 1883); 90 additions to vascular plants of Thames district (J. ADAMS 1884); Stewart Island[1]) (T. KIRK 1885); Mt. Te Aroha (J. ADAMS 1885); 131 additional species to the flora of Nelson (KIRK 1887). An account of the naturalized plants near Wellington was published by KIRK in 1877. An important illustrated paper by BUCHANAN on the alpine flora appeared in 1883. G. M. THOMSON dealt with the pollination of New Zealand plants and in the same year (1882), he published a notable paper on the origin of the flora. During this decade some much-needed studies on certain genera were made, especially *Veronica* (J. B. ARMSTRONG 1881), *Carex* (CHEESEMAN 1884) and *Coprosma* (CHEESEMAN 1887). BUCHANAN's fine folio work on the indigenous grasses appeared in 1880, illustrated with life-size figures. C. KNIGHT (1884) published 38 new species of lichens. The New Zealand University, founded in 1870 began extremely slowly to influence research, and the early papers on *Algae* of R. M. LAING (1886) may be traced to its influence. G. M. THOMSON's useful book on ferns came out in 1882, and the same year POTTS's charming "Out in the Open" containing interesting botanical observations was published.

The third decade must be extended to 1898 and up to April 10th 1899. The botanical exploration of New Zealand still continued. CHEESEMAN visited the unbotanized Three Kings Islands and the almost unknown Kermadec Group, publishing lists of their species and other details (1888—91). KIRK voyaged to the New Zealand Subantarctic Islands in the summer of 1890, putting forth in 1891 an account of the botany of the group (Macquarie Island excepted), that of the Snares and Antipodes Islands being previously unknown. Mr. JUSTICE CHAPMAN, of the same expedition, also contributed some important particulars on their vegetation (1891). J. ADAMS ascended Mt. Te Moehau and Hikurangi describing their vegetation (1889—1897). HAMILTON wrote an account of his visit to Macquarie Island (1895). PETRIE made a number of interesting journeys, collecting copiously[2]). COLENSO was still active. MACMAHON ascended Mt. Stokes. H. J. MATTHEWS collected near L. Wakatipu for his famous garden. F. A. D. COX made fairly full collections of the Chatham Islands plants. L. COCKAYNE commenced his botanical explorations in 1887 and has continued them yearly up to the present time[3]). In 1896 PETRIE's highly important "List of the Flowering plants indigenous to Otago" appeared[4]). The

1) Details are given regarding the vegetation, together with an account of the first ascent of Mt. Anglem. A few additions are made to the seed-plants and there is a full list of ferns. Mr. TRAILL materially assisted the author.

2) Ruahine Mts., Volcanic Plateau, Clinton Valley, Waimakariri Basin and N. Westland, Mt. Hikurangi, many parts of Auckland.

3) For the decade these included: Humboldt Mts., Puketeraki Mts., the neighbourhood of the Waimakariri and its main tributaries, the Seaward Kaikoura Mts., N. Westland, the neighbourhood of L. Wakatipu, and various localities from N. Canterbury to Foveaux Strait.

4) This represents, in small compass, the wealth of information regarding the species and their distribution that this ardent botanist had acquired during 20 years of careful observation. Especially well had he examined the mountains and valleys of Central Otago which had yielded an amazing harvest.

same year DIELS' "Vegetations-Biologie von Neu-Seeland" was published, a pioneer work which laid securely the foundations of ecological botany in New Zealand. The study of mosses by R. BROWN and T. N. BECKETT formed a feature of this decade, BROWN, whose love of botany was intense, publishing many supposed new species[1]) year by year up till his death. The veteran COLENSO forwarded large consignments of *Hepaticae* to Kew, and these, determined by STEPHANI, yielded many species new to the flora. An important work of this decade was the determination of New Zealand tertiary fossil plants by ETTINGHAUSEN. In 1897 New Zealand science experienced a great loss in the sad death of Mr. T. KIRK. For about 34 years all his time and energy had been devoted to New Zealand botany. Early on, he became leader of botanical thought in the Colony, and that position he held firmly till his death. The incomplete flora which KIRK had prepared at the instance of the Government appeared in 1909. Though lacking the author's guiding hand, it is a fine piece of work, and one can but deeply regret its non-completion.

b. From 1899 *to the Publication of Cheeseman's "Manual" in* 1906.

The 8 years of this short sub-period show a decrease in contributions to New Zealand botany. Nevertheless, this was more apparent than real, for there was much activity that did not appear until the publication of CHEESEMAN's "Manual", many collectors[2]) having been busy supplying that author with material.

In 1899, L. COCKAYNE commenced his ecological publications with a paper on the burning and regeneration of subalpine scrub[3]). LAING continued his much-needed papers on algae (1900, 5, 6), BROWN his papers on mosses, and CARSE wrote a detailed paper on the botany of Mauku. The influence of the University somewhat increased, as shown by an important paper by Prof. A. P. W. THOMAS on the prothallus of *Phylloglossum*, and several papers by students of Canterbury College. R. M. LAING and Miss E. W. BLACKWELL wrote a popular book, entitled "Plants of New Zealand" (1906), which is profusely illustrated by excellent photographs and contains a good deal of ecological information. In 1906 CHEESEMAN's "Manual" appeared, he having been employed by the Government for its production. It showed how great the progress in floristic botany had been since the publication of the "Handbook" in 1867, the species of Siphonogams (Spermophytes) having been raised from 935 to 1415.

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1) Probably many will be invalid. He commenced publication at an advanced age and worked under extreme disadvantages.

2) One of the most active was Mr. TOWNSON, who made a close examination of W. Nelson, hitherto unbotanized, and threw a flood of light on its remarkable florula. Mr. F. G. GIBBS did excellent service in many parts of Nelson over a wide area and discovered many novelties. Messrs. H. J. MATTHEWS, T. H. MACMAHON, H. CARSE, and R. H. MATTHEWS also supplied CHEESEMAN with abundant material.

3) This was followed by communications dealing with seedlings (1899, 1900, 1901), Plant-geography of Waimakariri (1900), Chatham Island (1902), Subantarctic Islands (1904) and several shorter papers.

With the appearance of this work the gifted author sprang at once into the front rank of the floristic botanists of the day. The descriptions are wonderfully accurate, the judgment in critical cases sound, and clerical errors are negligible. Perhaps the author might be accused of too great caution, but such an accusation is itself praise.

c. From 1906 *to the end of* 1913.

The appearance of the "Manual" gave a fresh impetus to research. The ormer collectors, their ranks increased by younger naturalists, enabled CHEESEMAN almost yearly to bring out papers supplementary to his work; the number of ecological students also gradually increased. The Government employed L. COCKAYNE to make a series of botanical surveys and the following reports were the result: Kapiti Island (1907), Waipoua Kauri forest and Tongariro National Park (1908), Stewart Island (1909) and two on Sand-dunes (1909—11). The Philosophical Institute of Canterbury organised an expedition to the Lord Auckland and Campbell Islands and published a work in 2 volumes which *inter alia* contains a full account of the botany of the Subantarctic botanical province, the article by CHEESEMAN on the affinities and history of the flora being of special merit. R. B. OLIVER, who with some companions, spent a year on the Kermadec Islands in order to study their natural history, wrote an admirable account of their vegetation and flora. LAING, D. L. POPPELWELL, PHILLIPS TURNER, B. C. ASTON, PETRIE, J. CROSBY-SMITH and H. CARSE dealt respectively with the botany of the Spenser Mts.; certain parts of Stewart Island and the South Otago district; the Waimarino forest; the Tararua Mts.; Mt. Hector and the denuded area of Central Otago; the Princess Mts. (Fjord district) and Mangonui County. Local lists of species were published by TOWNSON (N. W. Nelson), ASTON (Wellington), L. COCKAYNE (Franz Josef glacier and neighbourhood, Clinton Saddle and vicinity). The influence of the New Zealand University increased to some extent and several papers of value were published by students[1]).

Abroad an increasing interest was taken in New Zealand plants. GOEBEL, who had visited the Dominion in 1898, wrote an important paper on certain *Muscineae*, and his "Experimentelle Morphologie" contains many observations regarding New Zealand plants, while more recently he has described the life-history of *Loxsoma*. Various parts of "Das Pflanzenreich" deal with critical New Zealand genera, especially *Luzula* (BUCHENAU), *Uncinia* and *Carex* (KÜKENTHAL), *Halorrhagis* and *Gunnera* (SCHINDLER) and *Sphagnum* (WARNSTORF). H. N. DIXON has commenced a critical study of New Zealand mosses, and a valuable paper on *Dicranoloma* has already appeared. The embryology of the New Zealand *Coniferae* has received considerable attention at the hands of botanists at Chicago University, E. C. JEFFREY of Harvard and others.

1) The following may be cited, — Young Stages of Cyathea and Dicksonia (G. B. STEVENSON); Anatomy of Lycopodium (J. E. HOLLOWAY); Fungi of Epiphytic Orchids (T. L. LANCASTER); Anatomy of Subantarctic Plants (Miss HERRIOTT); New Zealand Halophytes (Miss CROSS).

Miss GIBBS has written on the female strobilus of *Podocarpus*. KIDSTON and GWYNNE-VAUGHAN have described two Jurassic *Osmundaceae*. MASSEE continued his excellent papers on New Zealand fungi. BITTER, in his elaborate work on *Acaena*, has described many new forms for New Zealand. The studies of BEAUVERD have cleared up several doubtful points regarding the Gnaphaloid *Compositae*. DOMIN has shown the New Zealand species of *Koeleria* to be distinct from any in Europe or South America. Mr. D. G. LILLIE, biologist on the Terra Nova, made large collections of Jurassic plants in New Zealand. These are being carefully examined by ARBER who has already cleared up many doubtful points. At the time of writing various interesting papers relative to New Zealand botany are in the press, and at no time have there been so many workers or greater botanical enthusiasm.

Chapter II. Bibliography.

No space is available for anything approaching a full list of the literature pertaining to New Zealand botany. Papers merely describing new species, or such as are purely morphological or phylogenetic are not cited as a rule, and many of quite minor importance are omitted. It follows then that the list does not reflect in full the botanical activity of certain workers, especially KIRK, COLENSO, PETRIE, CHEESEMAN, BUCHANAN and R. BROWN. On the other hand, a few works dealing with floral relationships with other lands are cited, as also others purely geological or geographical on which, it may be, statements in the book are based. Citations in the body of the work with author's name and date refer to this bibliography. T. N. Z. I. means Transactions and Proceedings of the New Zealand Institute.

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Part I.

Sketch of the Physical Geography and Climate of New Zealand.

Chapter I. Physical Geography.

1. General.

The New Zealand botanical region comprises those islands lying in the S. W. Pacific between the parallels of 30° and 55° S. lat. and 158° 56′ E. and 176° W. long. The archipelago, if it may be so termed, consists of the following distant groups of islands, — the Kermadecs, the Islands of New Zealand proper, the Subantarctic Islands of New Zealand and the Chatham Islands. The total land-area of the region is about 104,581 sq. km.

New Zealand proper consists of two large islands, the North and the South and the much smaller Stewart Island. The above, together with some other small islands and islets including the Three Kings in the N., lie between the 34° 6′ and 47° 20′ parallels of S. lat. and the meridians 166° and 179° E. long. They constitute the Northern, Central and Southern botanical provinces of this work.

The North Island has an area of 44,468 sq. km; its length is 829 km and its greatest breadth 450 km. The area of the South Island is 58,525 sq. km, its length 845 km and its greatest breadth 290 km. Stewart Island has an area of 664 sq. km and is about 48 km in length.

The long isolation of New Zealand far from other land masses is a matter of profound significance with regard to the flora. Tasmania, the nearest land of importance, is about 1500 km distant. The actual Australian continent is somewhat further away (1650 km). Norfolk Island is 750 km from the North Island. South America is distant 6483 km from the Chathams and 7700 km from New Zealand. Finally, the Antarctic Continent (C. Adare) is 2750 km from Macquarie Island and 3700 km from the South Island.

A consideration of the ocean-depths in the neighbourhood of the New Zealand archipelago both serves to emphasize the isolation of the region and to show how wide-spread would be the effect of a general considerable elevation of the ocean-bed. The 180 m line follows rather closely the outline of the present main islands and includes the adjacent small islands together with the Three Kings, Stewart Island and the Snares. The 900 m line conforms closely to the above line on the E, but westwards it extends a considerable distance from the land reaching a maximum of 500 km, while to the S. it goes beyond the Lord Auckland's Islands. The 1800 m line includes the whole archipelago except Macquarie and Kermadec Islands, and, extending far to the north-west, it reaches to within comparatively close proximity to the Queensland coast while Lord Howe and Norfolk Islands come just within its bounds.

2. Physical Features of New Zealand proper.

a. The North Island.

Mountains. The land-surface is frequently much broken and, in parts, mountainous. The main range extends from the east of Wellington Harbour to the East Cape. The highest peaks are in the Ruahine and Tararua Mts., but none reach 1800 m and few more than 1520 m. The rocks are chiefly mudstones, sandstones and greywacke.

The centre of the island is a volcanic plateau much of which is at an altitude of more than 600 m, but, northwards, gradually becoming lower, it extends to the Bay of Plenty. This area, within recent geological times has been exposed to powerful volcanic action. The eruptions have been largely explosive and the present surface-pumice is the result. Even yet there is much thermal activity in the shape of boiling springs, geysers, mud volcanoes &c. especially on the line of a fissure connecting White Island, a volcano in the solfatara stage, and Ruapehu. From the highest portion of the Plateau rise the semi-active volcanoes, Ruapehu (2803 m), Ngauruhoe (2291 m) and Tongariro (1968 m). The crater of Ruapehu is filled with ice, in which lies a lake of, sometimes, extremely hot water while small glaciers extend over the crater-rim and descend to comparatively low levels in the gullies.

Mt. Egmont (2514 m) in Taranaki is an extinct volcano standing far isolated from other mountains; its summit carries perpetual snow.

In 1886, the supposed extinct volcano Tarawera, situated on the Volcanic Plateau burst forth forming a rent 14.4 km long with a mean width of 108 m and ejecting light scoria and volcanic dust over an area of 15,000 sq. km.

The remaining North Island mountains, with the exception of the Cape Colville Range[1]), are not lofty enough to bear a subalpine vegetation, but nevertheless the following ranges show distinct belts of vegetation. — The Maungaraki Mts. (900 m), extending northwards from C. Palliser; the Puketoi Hills (610 m), in the east of Wellington; the volcanic Mt. Karioi and Mt. Pirongia near the coast of S. W. Auckland; the high land culminating in Mt. Tutamoe (800 m), south of Hokianga Harbour, and the high land north of the latter with Mt. Raetea (800 m).

The extreme north of the island consists of a small, narrow much dissected tableland some 300 m high, formed of hard igneous and sedimentary rocks.

1) This extends from the Great Barrier Island through C. Colville Peninsula southwards almost to Rotorua. The rock is volcanic overlying highly denuded mudstone and greywacke.

At one time this was disconnected from the mainland, but now is united by a narrow spit of recent and consolidated dunes.

Plains. An extensive plain of marine origin, the Wanganui, occupies the S.W. of the island extending to Ruapehu where it is over 600 m altitude. The rock consists of marl enclosing beds of shells. This plain is deeply cut by numerous streams so that, in many places, there is a network of deep gorges, often extremely narrow. Viewed from the bed of one of the larger rivers, the nature of the surface could hardly be guessed, steep hills rising on either side giving the impression of a truly mountainous land.

River-formed gravel plains occur east and west of the main range (Manawatu, Wairarapa and Hawkes Bay Plains).

The Waikato Plain occupies much of southern Auckland; it extends from the Frith of Thames to the R. Waipa. Its surface, rarely more than 30 m above sea-level is extremely wet and swampy. Northwards from the Auckland Isthmus there is much low-lying ground.

Rivers. The land throughout is well watered every gully containing its running stream. In many places the rivers have cut deeply into the surface, so that gorges are a familiar feature. The rivers rising in the high mountains are of a torrential character, but this feature is much less marked than in the South Island, while gently flowing streams are more common. Where the rivers have not cut deep beds the adjacent land is liable to be flooded and extensive swamps are so formed (Manawatu, Waikato, Thames, Northern Wairoa, Awanui). The rivers Waikato and Wanganui are the most important in point of size and drainage area.

Lakes. The largest lakes are on the Volcanic Plateau, the most important being L. Taupo. L. Waikaremoana in the East Cape District is at 600 m above sea-level. So far as plant-life is concerned it is the natural ponds and shallow lakes met with in many places that are of most importance.

Sea-coast. The coast is about 3,520 km in length. The various outlying islands also furnish coastal conditions. A most important feature of the coastline is the extensive dune-area of much of the W. coast which extends inland in places for 12.8 km. Also, there are considerable dunes in the far N. and N.E., on the coast of the Bay of Plenty and at various places between Poverty Bay and C. Turnagain.

The coast is rocky in many places. The S. and S.E. coast-line in its southern part consists of cliffs of slaty shale. Further north, low cliffs of soft marl and mudstone occur fronted by a narrow beach with the stony surface worn quite flat. The N.E. coast consists at first of steep slaty cliffs, but from Opotiki onwards the land as a rule is low. The shore-line of the Coromandel Peninsula consists mostly of slate cliffs, but volcanic rock is not uncommon. From Auckland to the North Cape the coast is much broken and presents a great diversity of stations for plant-life. Low cliffs fringed by a sandy or stony beach are common. There are bold rocky headlands. Many of the rivers have wide mouths, but these are shallow and mud-flats are exposed at low water. The short N. coast is frequently precipitous through truncation of the tableland. The North Cape is almost an island.

Where dunes are absent on the S.W. and W. coasts there are cliffs some volcanic (Maunganui Bluff &c.), others limestone (Kawhia, W. of Taranaki &c.) and others of slaty shale (Reef Point, South Waikato Head &c.).

Many kilometres of coast are without inlets, estuaries &c. With the exception of Wellington and Porirua Harbours in the S., nearly all of any moment are to be found on the E. and W. coasts of Auckland.

b. The South Island.

Mountains. The surface is extremely mountainous. Commencing in the S. there are two chains [1]), the one composed of gneisses and granulite on the W., and the other of schist extending from the shore at Dunedin and joining the former between Lakes Wakatipu and Wanaka. As the Southern Alps they are continued in an unbroken line to Cook Strait. All the eastern slopes are formed of slaty shales and greywackes. Below the shales &c. on the W. the rock is schist, but at low levels occasionally gneiss. Granite occurs in a few places. The loftiest peaks are situated at about the centre of the chain. They vary from some 3000 m to 3766 m (Mt. Cook). Proceeding N. and S., the range gradually decreases in height, but few peaks are lower than 1800 m. Many lofty ranges and spurs extend eastward for 48 km or thereabouts from the main Divide. These eastern mountains are especially characterized by the vast masses of unstable débris covering their slopes and locally known as "shingle-slips".

The snow-line in the Southern Alps is probably, on an average, at about 2200 m, but it is not uniform and varies according to latitude, while also it is lower on the W. than on the E. The central part of the range is heavily glaciated, the size of the glaciers being correlated with the altitude of the peaks. The Great Tasman glacier is about 29 km long and its terminal face 718 m above sea-level. On the W., the Fox and Franz Josef glaciers descend to less than 210 m altitude. Glaciers are wanting to the S. of lat. 45° and in the N. they cease at a little to the N. of lat. 43°. The eastern valley glaciers are generally covered with an enormous amount of moraine.

The central Southern Alps form an unbroken wall, but to the N. and S. there are numerous passes, the lowest being the Haast (570 m).

Besides the Southern Alps there are other lofty ranges. The Kaikoura Mts., two high parallel ridges in the N.E. of the Island, are possibly a continuation of the North Island Dividing Range. Several of their peaks are more than 2400 m high; they carry neither glaciers nor perpetual snow except in patches; their débris fields are of enormous extent. West of the Southern Alps in the N.W. are several rugged ranges extending from near Greymouth to the N. coast, the highest peaks of which frequently attain an altitude of

1) See Marshall 1912a: 4.

1500 m. They consist, according to MARSHALL, of large intrusive granite masses on the western side but on the eastern sediments of Ordovician and Silurian age, schists and marbles extend for a distance of 32 km. Banks Peninsula on the E. of Canterbury is formed of much denuded volcanic rocks of Tertiary age reaching a maximum height of about 900 m.

Plains. Gravel plains formed by glacial or snow rivers are a striking feature of South Island topography. The most important are: — The Canterbury Plain (161 km long by 48 km wide at its widest); the long narrow Westland coastal plain (200 km long by 10 km wide) and the Southland Plain extending from the lakes to Foveaux Strait. Flat as the Canterbury Plain appears to the eye, the surface near the foot-hills of the Southern Alps is more than 457 m above sea-level. Borings for artesian water shew by the peat-deposits at different depths that there have been several changes in the land-surface during the formation of the plain.

Rivers. The numerous rivers issuing from the glaciers or fed by melting snows or frequent downpours are torrential at first their beds full of huge rocks over which the waters leap and foam. By degrees, the valleys shaped by former glaciers, widen and are filled from side to side, it may be, by a flat stony bed over which, in anastomosing streams, the river wanders. Lower down, as the valley widens still more, or when the plain is gained, the river may flow between high permanent terraces that it has built, and frequently there is a series of such at different levels with portions of the ancient flood-plains at their bases. River-beds 1 km or more wide with terraces on either side are a common feature of the gravel-plains.

Where a tributary stream in a mountain-valley joins a river the shingle of its bed spreads out as a fan. Such are present at the mouth of almost every gully, sometimes naked and active, at other times plant-clad and passive.

Former Glaciation. Equally important both physiographically and ecologically is the question of the extent of the former glaciation, a matter regarding which geologists are not in accord. PARK holds that the ancient glaciers extended on the E. throughout the South Island to the present coast-line, but MARSHALL is of opinion that, except near Taieri Mouth, they did not go beyond the river-valleys (1911: 31). Be this as it may, the mountain landscape furnishes absolute proof of a most extensive glaciation with its ancient moraines of great size, roches moutonnées, ice-shorn hillsides, truncated spurs and U-shaped valleys. Glacial lakes too are frequent from small tarns on moraines to the great sheets of water, frequently extremely deep, of Otago and Canterbury.

PARK has also attempted to prove that the glaciation extended to the North Island, but his views are not, as yet, accepted by geologists in general. The gradual decrease in self-evident glacial features of the landscape from the Waimakariri valley northwards, the presence of moraines in the Lord Auckland Islands *only* on the hills, and the absence of moraines and ice-scratched rock on the North Island Dividing Range, let alone much adverse biological evidence, cast the gravest doubts on PARK's views.

As to the cause of the New Zealand glacial period, the general view is that it resulted from elevation of the land, and botanical evidence supports this theory. But it may have been due to a colder climate, while greater catchment-areas, as HAAST and MORGAN have maintained, would also cause glacial extension.

Sea-coast. The coast-line in general is little broken. Notable exceptions are the Marlborough Sounds and the S. W. Otago fiords, the former drowned river-valleys and the latter of glacial origin. Banks Peninsula contains a number of inlets, some originally volcanic craters. There are also a few shallow estuaries, more or less closed by sand or gravel spits, in the S. E. and N. whose floors are partly bare at low-water.

In many places the coast is low and the shore sandy, so that long stretches of dunes occur, the most important being Farewell Spit and areas in the N. E., E. and S. Shingly shores correlated with the great river-beds are frequent in many parts.

The coast is frequently rocky, where mountain-ranges or hills come to the shore-line, as in the S. E., Otago and Banks Peninsulas (volcanic), Amuri Bluff and Kaikoura Peninsulas (limestone), the N. E., N. and N. W. (granite) and the S. W.

Coastal islands are few. The more important are those to the N. of Marlborough and those in Foveaux Strait. The Open Bay Islands on the W. are composed of limestone, and although mere islets they possess a remarkable plant-covering.

c. Stewart Island.

Stewart Island lies about 25 km from the South Island from which it is separated by Foveaux Strait, this nowhere more than 48 m deep.

In shape the island is irregularly triangular. The surface is hilly, much broken and in parts mountainous, the peaks varying from 676 m to 975 m. There is but little truly flat ground. East of the central range the land is low, but broken. At the head of Paterson Inlet a narrow valley, the Freshwater, extends northwards to the Ruggedy Mts., while eastward a depression widening out into an ancient dune-area connects the valley and the W. coast. West of Port Pegasus there is some low boggy moorland.

The coast is, in general, rocky. At Mason Bay, on the W. is an extensive dune-area.

Perhaps the most striking features of the island are Paterson Inlet and Port Pegasus. The former, a broad lake-like expanse of water, irregular in shape, enclosed by hills and dotted with forest-clad rocky islets, extends westward for 17 km putting forth three diverging arms. Port Pegasus, situated in the S., runs parallel with the S. E. coast for about 12 km, its entrance blocked by three islands.

There are a number of outlying rocky islets especially to the E. and S. W., while to the N. W. is the fairly large Codfish Island. Thirty-two kilometres to the eastward is the flat island of Ruapuke 7.6 km long by 3.4 km wide.

Stewart Island and its outlying islands are composed mostly of granites and diorite gneiss, but the central range is built out of a schist similar to that of Central Otago.

Well preserved dunes in the inland valleys of Paterson Inlet show that the land-surface has at one time been depressed, at which period there would be probably four islands.

3. Physical Features of the Outlying Islands.

a. *The Kermadec Islands.*

The Kermadec Islands are four in number. They extend from 29° 15′ S. lat. and 177° 59′ W. long. to 31° 24′ S. lat. and 178° 51′ W. long., and are distant about 1000 km from New Zealand. The group is volcanic, but it stands on a submerged plateau, part of a ridge connecting New Zealand with Tonga. Outside the plateau the ocean is 2700 m deep.

Sunday Island, the largest of the group, 10.3 km long and 29.25 sq. km in area, reaches a height of 524 m. It is composed chiefly of pumiceous and other tuffs (OLIVER 1910: 123); lava streams are few. The surface is hilly with many narrow spurs separating deep gullies. These spurs, truncated at the coast, drop as sheer precipices to the water for 200—300 m. The greater part of the island is a crater, its rim 55 m above sea-level in the N., elsewhere averaging over 300 m. There are three small crater lakes near one of which (CHEESEMAN 1888: 153) steam issues. There is a small sandy beach in the N., and at Denham Bay, where there is a little level ground, one of gravel.

Macauley Island, distant 109 km from Sunday Island, is 2 km long, 3 sq. km in area, and its highest point 237 m above sea-level. Cliffs everywhere fall to the sea.

Curtis Islands, 35 km from the last-named are two rocky islets with an area of 6 sq. km and the highest point 100 m. The crater-floor contains hot mud, boiling springs and sulphur.

b. *The Chatham Islands.*

The Chathams consist of four islands and several detached islets and rocks lying between the parallels of 43° 35′ and 44° 25′ S. lat. and the meridians of 176° and 176° 55′ W. long, and are distant from C. Palliser, Cook Strait, 717 km.

The main island, Chatham Island, 869 sq. km in area, has somewhat the shape of a horseshoe. Generally the land is low but undulating. Much of the interior is occupied by the Te Whanga lagoon which, roughly triangular, extends from the N. coast southwards for 25 km and, at its greatest breadth is nearly 15 km wide. On the E. it is separated from the sea by a very narrow strip of land broken through at one point. South of the lagoon the island is a compact four-sided block, which, in comparison with the remaining land looks quite hilly but its highest part is only 286 m and the culminating point of the main ridge about 2 m lower. From this ridge, a table-land, looking like an ancient sea-bed, extends southwards terminating in abrupt cliffs 182—213 m in depth irregularly cut by small streams. Here and there conical volcanic hills, 152—182 m high, stand out from the flat, northern and central portions of the island.

The extensive coast-line varies from flat ground bordered by dunes or low rocks to the high cliffs of the S. and SW.

Besides the Whanga, there are many other lagoons and lakes, indeed, it is stated that one-third of the surface is occupied by water. Bogs of great extent and depth are a familiar feature both of high and low ground. Small, sluggish streams of peaty dark-brown water are abundant, but, at most only two can be considered rivers.

Pitt Island, 13.6 km long by 6 km across, lies about 22 km to the south of the main island. Its coast is rocky.

The remaining islands (Mangere, South-East Island) are quite small, but the latter rises to 184 m.

The major part of the Chathams consists of volcanic rocks (basalt, tuffs) covering an ancient land-surface. Schists occur in the N. of Chatham Island and limestones on the W. of the great lagoon, on the N. and on Pitt Island.

c. The New Zealand Subantarctic Islands.

1. General.

These consist of several distant groups lying between the parallels of 54° 44′ and 47° 43′ S. lat. and 159° 49′ and 179° E. long. The names, distance and direction of each group from the South Cape of Stewart Island are as follows: Snares, 113 km, S. S. W.; Lord Auckland Islands, 348 km, S. by W.; Campbell Islands, 608 km, S. by E.; Macquarie Islands, 1049 km, S. W. by S.; Antipode Islands, 902 km, E. S. E.; Bounty Islands, 902 km, E.

The islands, excepting the Bounties and the Snares, are chiefly of volcanic origin, and, the Bounties excepted, the surface consists in general of a deep layer of peat.

2. The Snares.

The Snares consist of North-East Island, about 2 km long by 0.8 km wide, rising perpendicularly on its S. side to 131 m, and of four other rocky islets lying to the S. W.

The main island has a rocky, precipitous coast-line, except in one place on the E. side where a small stream enters the sea. The island is formed of a pale moderately coarse muscovite granite.

3. The Lord Auckland Islands.

The Lord Auckland group consists of two fairly large islands, Lord Auckland Island, 40 km long by 27 km wide in its widest part and Adams Island, 24 km long and 9 km wide in its widest part, together with a group of smaller islands (Enderby, the largest, Rose, Ewing and Ocean) to the N. and the small Disappointment Island on the W.

Adams Island is separated from Lord Auckland Island by Carnley Harbour, the site of an old volcano. It is a fairly even ridge, 600 m high, with a long slope northwards, but on the S. descending to the sea in a sheer precipice.

Lord Auckland Island is also high and rises, in more than one place to 600 m. Several arms from Carnley Harbour pierce it in the S. On the E. are a number of small fiords the result of ice-action, but on the W. there is a perpendicular wall of stupendous cliffs.

The islands in the N. are separated from Lord Auckland Island by Port Ross, a land-locked sheet of water. They are quite low but their coasts are rocky. On Enderby Island there is a sandy beach, 8 km long backed by low dunes.

Disappointment Island, some hundreds of metres high with cliffs on all sides is about 3 km in length.

Rivers of considerable size for so small a land-area fill the valleys of the two larger islands. The watershed of Lord Auckland Island is close to the summit of the western cliffs. There are one or two small mountain lakes.

Besides volcanic rocks there is an outcrop of granite and gabbro at Carnley Harbour.

There is abundant evidence of glacial action, but according to SPEIGHT[1]) it is improbable that the islands have been completely covered by ice.

4. The Campbell Islands.

There is a main island, Campbell Island 48 km in circumference, but the other members of the group are mere rocks. The northern end of the island rises as a whole to about 300 m, but in the S. there are a number of isolated peaks, the highest about 400—500 m. Two long inlets pierce the land on the E.

The rocks are in part volcanic and in part limestone containing fossils. According to MARSHALL[1]) the surface-features are due to glacial action, but there is no evidence that the island was covered by an ice-sheet.

5. Macquarie Island.

According to SCOTT (1883: 486), Macquarie Island is exceedingly hilly, the hills rising to perhaps 280 m, while numerous tarns lie amongst their hollows. The coast-line consists principally of cliffs with a few shingle beaches. Possibly the island is 30 km long. The rocks, so far as known, are volcanic.

6. The Antipodes Islands.

There are two islands, Antipodes (8 km long by 4.6 km at its widest) and Bollons Island, quite small but 150 m high. The surface of the main

1) Subantarctic Islands of New Zealand. 1909.

island is an undulating plateau, Mt. Galloway the highest point, reaching 530 m. The coast consists of high perpendicular cliffs. The rocks, so far as known, are basalts.

7. The Bounty Islands.

These are a small group of rocky islets and rocks formed of a pale biotite granite. The largest island is 1 km long by 0.8 km wide and 88 m high. The surface is without a true soil and is polished smooth as glass by the millions of penguins and other birds, also by numerous fur seals. Quantities of guano accumulate during the breeding season of the birds, but the greater part is removed by the rains of winter.

4. The Soils of the New Zealand botanical region.

Regarding the soils of New Zealand little accurate information is available. Such knowledge as exists is derived from a few analyses by ASTON, rapid field-observations and the experience of agriculture and horticulture. Here then merely general and guarded statements are made. Certain special details are given when dealing with the formations.

The most widely spread soils are: — Loess, pumice, clays of various kinds, marls, sand and stony débris. Common, but of more local distribution are: — Alluvial loams, peat including raw humus, soils from basic volcanic rock, salt-soils and rock. The following are quite local: — Sulphur &c. soils in vicinity of hot-springs &c., serpentine soils, soil heavily manured by sea-birds.

Loess soils occur over wide areas in the South Island. They have arisen from silt blown from the glacial river-beds; such accumulation and transport still goes on. Loess is frequently mixed with clay derived from the underlying rock or of glacial origin. Loess, pure or mixed, is the principal soil to the E. of the Divide in the South Island.

Pumice soils play a large part in the centre of the North Island and the land adjacent. When pure, unweathered and perhaps mixed with scoria, they provide, even in a wet climate merely steppe or desert conditions. When weathered and mixed with humus, pumice soil is fertile enough, as the farms of the Waikato, and, in part those of Hawkes Bay, bear witness.

Clay soils of various kinds are common in the North, South and Stewart Islands. The extremely abundant greywacke readily weathers into clay. The low hills and undulating ground of lowland Auckland, known as the "gumlands" are covered with a great depth of specially impervious clay deficient in humus, which though variable in quality is generally extremely poor. This is especially so with the white clays locally termed "pipeclay". The Stewart Island clays are formed from granite. Glacier clay occurs on mountain slopes and river-valleys. The fertility of these clay soils is governed by the drainage-conditions and the percentage of humus. Frequently clay becomes hard and dry during a period of drought, and it then offers a most unfavourable station for plant-life.

Marl soils occur on the Wanganui coastal plain, in some parts of Hawkes Bay and locally in various places. Sandy soils are frequent on and near the coast, and arise either as blown sand from the shore or from the disintegration of soft sandstone. They are also frequent on the gravel plains.

Alluvial loams form the bulk of the soil of lowland valleys in both Islands.

Humus soils are of widespread distribution. They occur at all altitudes and vary from a thin surface-layer to peat-deposits, 12 m deep, as in the Chatham and Lord Auckland Islands. The rain forest climate is eminently favourable for the production of humus. The subantarctic and wet high mountain climates favour the formation of raw humus and peat.

Volcanic soils, though of wide occurrence in many parts of the New Zealand region, are generally local and limited in extent. They are specially fertile and the distinction between the vegetation of volcanic and "gumland" soils in Auckland is striking. The other soils mentioned above need no special comment here.

5. The Geological History of New Zealand.

Although there are rocks in New Zealand of Archaean and Palaeozoic age nothing is known as to the geographical conditions of their deposition. New Zealand, as a permanent land, dates only from the Mesozoic period. It was then, according to MARSHALL, "That the great series of folded stratified rocks of which the main mountain-ranges are constituted were deposited during a long continuous period, lasting almost throughout the Mesozoic age, when the present position of the country was on, or near the shore-line of a great continent" (1912b. in Author's preface), which "stretched far to the westward and probably united New Zealand with Australia" (1912a: 35).

At the close of the Trias-Jura period the Mesozoic sediments were folded and greatly elevated, the land eventually extending to New Caledonia or further northward, to the Chathams in the E. and to Campbell Island, or beyond in the S.

In early Tertiary times a great depression set in, which continued until the semi-continent became but a chain of small islands. During the depression, but by no means synchronously, many of the coal-beds were formed. In various localities there were volcanic outbursts (e. g. N. of Auckland, Coromandel, Banks Peninsula, Oamaru).

During the Pliocene, but perhaps earlier, elevation once more took place and continued into the Pleistocene, the land-area being vastly extended to include all the present outlying islands, except perhaps Macquarie and the Kermadecs. This was the period of the glacial epoch already discussed. Egmont continued active, Ruapehu burst forth at this time, or perhaps earlier, and much pumice was ejected from the site of Lake Taupo; also the volcanic area of the Auckland Isthmus and its vicinity probably dates from this period.

The late Pleistocene was a time of depression; the land sank below its present level but the fall was far from uniform, as judged from ancient gravel beaches which vary from 40 m to 150 m above sea-level; the glaciers retreated, their valleys were deeply covered with gravel and coastal valleys became inlets.

This depression has been succeeded by a continuous but slow elevation lasting to the present time throughout the Recent period. Raised beaches are a frequent feature. The great river-terraces were constructed. Ngauruhoe came into eruption and the other volcanoes of the Plateau were more or less active. Rock-movements are still in progress as evidenced by the frequency of earthquakes.

Chapter II. The Climate of New Zealand.

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1. General.

New Zealand possesses, for the most part, a maritime climate, situated as it is remote from other lands in the widest ocean of the globe with no part of the area more than 120 km from the sea. There are however marked differences in climate, owing firstly to the region extending through 25 degrees of latitude and secondly to the lofty mountain chains of the main islands lying athwart the prevailing winds. "Aspect" therefore has a remarkable influence both on rainfall and temperature, not only as to average annual amounts, but also in every atmospheric disturbance that passes over the land. Seasonal differences stand out clearly enough; thus the W. coast has a lower mean temperature in summer and spring than the E. coast districts, but for autumn and winter the reverse holds good.

With regard to rainfall, that of the South Island, in the W., is extremely high, while, on the contrary, parts of the eastern districts are, in comparison, very dry. The North Island has a maximum rainfall — almost a rainy season indeed — in the winter months, but the South Island shows a remarkable evenness in its monthly averages. Periods of drought occur at times in the eastern districts, such being commonest in spring and summer, in the N., and in autumn and winter, in the S. Although the total average rainfall, especially in the E., decreases with increase of latitude, yet the number of rainy days is greater in the S. than in the N. This arises through the frequent occurrence of atmospheric disturbances in the latitude of the "forties", but the northern districts are under the influence of occasional cyclonic disturbances of tropical origin which travel from the N. W. to the S. E. over the North Island. Occasionally, extensive "Lows", decreasing northwards, account for much warm and moist weather but do not usually bring about a heavy precipitation. The cyclone track will often pass to the northward of New Zealand; sometimes it crosses as low as Cook Strait; occasionally it comes from the N. E. to the East Cape and then passes down the E. coast before taking an eastward route under the guiding and controlling influences of the prevailing westerly winds of these higher latitudes. The upper winds are almost invariably westerly and a divergence to a southwesterly direction from the W. usually precedes a marked change in weather conditions, which the forecaster values as a guide to the subsequent swing of atmospheric pressure. High pressure, or the anticyclone, may be regarded as the controlling factor of weather conditions and on the edge and between these high pressure systems are found the "Lows".

The frequency of the above disturbances judging from the average of 9 years are as follows: (1) For the cyclone or monsoon of marked intensity — Spring 2; Summer 1.8; Autumn 3.3; Winter 5.3. (2) For the westerly or antarctic low — Spring 6.3; Summer 4.3; Autumn 5.2; Winter 4.7.

2. Rainfall.

The rainfall of New Zealand bears a striking relation to the physical configuration of the region, and records gathered throughout the country during a period of 60 years present a certain regularity which clearly shows the dominating influence of the mountain ranges. In the South Island, the lofty Southern Alps, and in its N., the mountains of the North-western district, lie broadside to the prevailing westerly winds, and on their windward slopes are condensed the vapours which have been gathered by the breezes sweeping over vast stretches of ocean. On the Westland coastal plain, and on the adjacent rugged and precipitous slopes, the rainfall averages from 250 to 500 cm per annum, while on the leeside of the great mountain barrier the climate is, in comparison, extremely dry and, in places, the rainfall is only one tenth of that on the W. There are, in fact, two district climates, that of the W. strongly favourable to forest and that of the E. altogether antagonistic but in harmony with tussock-steppe. This latter climate, as will be seen further on, owes its character in part to the wind-factor.

While the South Island isohyets stretch E. and W., those of the North Island are more irregular in form, but demonstrate that the rainfall itself is more regular over the land as a whole and less extreme in a comparison between the different botanical districts. But here again the control of the mountains and plains over precipitation is apparent, the contours of the rainfall areas coinciding more or less with the configuration of the country, the heavier downpours occurring in proximity to Mount Egmont, the central volcanoes, the Dividing Range and the higher summits in general.

The mean annual rainfall of New Zealand, as derived from means of representative stations in various parts of the region, is about 121 cm, but the seasonal falls are far from uniform throughout. The following averages taken from the climatological tables give some idea of the rainfall and its distribution throughout the year for the two main islands of New Zealand.

Rainfall (in centimetres).

	Spring	Summer	Autumn	Winter	Annual
North Island..	31	25	34	36	126
South Island..	30	27	27	31	115

Rainy days (2 mm or more).

	Spring	Summer	Autumn	Winter	Annual
North Island..	45.5	30.3	39.1	47.1	162
South Island..	44.4	34.7	36.6	40.9	156

Annual rainfalls at certain representative stations (in centimetres).

North Island	Auckland 1) 61 years	New Plymouth 2) 37 years	Gisborne 3) 36 years	Wellington 4) 56 years
Average	109.8	150.9	118.9	126.4
Maximum	161.9	210.6	163.4	171.9
Minimum	86.9	111.3	66.3	76.3

South Island	Christchurch 5) 37 years	Hokitika 6) 35 years	Dunedin 7) 55 years	Invercargill 7) 18 years
Average	67.5	304.3	95.8	116.8
Maximum	90.3	392.2	138.5	165.3
Minimum	34.4	229.1	56.3	84.4

From the phytogeographical standpoint the number of rainy days is of far greater moment than the amount of the downpour, the following table then is of special interest.

Mean Number of Days with Rain (2 mm or more).

Locality	Jan.	Feb.	Mar.	Ap.	May	Jun.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Auckland	10.3	9.4	11.0	13.2	18.1	19.1	20.7	19.3	17.6	16.2	11.4	11.4
New Plymouth	12.5	10.5	12.2	14.0	18.0	17.2	19.5	19.2	17.5	18.5	15.7	14.2
Gisborne	9.0	9.7	12.3	12.4	15.6	16.4	16.8	15.7	13.4	11.6	11.6	9.3
Wellington	10.5	9.2	11.7	12.8	16.4	17.3	18.3	17.3	15.5	13.9	12.7	12.0
Christchurch	9.0	7.4	9.3	9.1	10.8	12.1	13.0	11.0	9.9	8.9	9.8	9.1
Hokitika	14.8	10.3	13.5	14.1	15.5	15.0	16.4	16.0	15.3	19.0	13.0	16.3
Dunedin	14.7	11.5	13.2	13.2	14.1	13.0	13.6	13.0	13.0	14.5	14.1	14.8
Invercargill	15.0	10.0	14.0	16.0	17.0	15.0	15.0	14.0	14.0	17.0	18.0	15.0

1) Junction of N. and S. Auckland districts. 2) Egmont-Wanganui district. 3) East Cape district. 4) Ruahine-Cook district. 5) Eastern district. 6) Western district. 7) South Otago district.

Annual mean totals: — Auckland 180.4; New Plymouth 189.7; Gisborne 153.8; Wellington 167.7; Christchurch 119.4; Hokitika 179.2; Dunedin 163.3; Invercargill 180.0.

3. Temperature.

Latitude, insolation, proximity to the ocean, or the large inland lakes, and height above sea-level are the determining factors with regard to temperature. Especially are the oceanic influences a master factor with regard to both summer heat and winter cold, upon both of which they exercise a moderating effect. Indeed, extremes of heat and cold, such as occur at similar latitudes in the Northern hemisphere, are absent throughout New Zealand at every altitudinal belt. The W. coast of the South Island lies open to the prevailing westerly winds and is more humid and equable than the eastern botanical districts which, generally speaking, possess a more or less continental climate with a considerable range of temperature. Near the coast of the North Island frosts, even on the grass, are of rare occurrence, but further S., and inland throughout, they are often experienced. Special details as to temperature are given further on when treating of the different districts and in the section dealing with the vegetation of the high mountains.

The meteorological seasons are later than the astronomical. Thus July is usually the coldest and wettest month in the year, while January is the dryest and warmest. The seasons may be roughly divided as follows: — spring, — September, October, November; summer, — December, January, February; autumn, — March, April, May; winter, — June, July, August. But such divisions are somewhat misleading from the phytogeographical standpoint, altitude latitude and aspect being controlling factors with regard to seasonal changes.

The following means (Centigrade) taken from the climatological tables give some idea of the temperature of the main islands: —

	Spring	Summer	Autumn	Winter	Year
North Island..	12.8°	16.5°	14.1°	9.5°	13.2°
South Island..	11.2°	15.2°	11.6°	6.5°	11.1°

4. Sunshine.

The following table shows the period during which the sun is above the true horizon on the days of midsummer and midwinter: —

Possible sunshine on the	Auckland		Wellington		Dunedin	
	Hrs.	min.	Hrs.	min.	Hrs.	min.
Longest day	14	40	15	10	15	46
Shortest day	9	38	9	13	8	39

The actual hours of bright sunshine recorded for Wellington City average nearly 6 hours per day throughout the year. The position is a critical one with regard to atmospheric disturbances, Cook Strait being usually the dividing line between the cyclonic storms and westerly low and, though sometimes escaping both, generally partaking of the changes due to the two. Other stations more protected from cloud formation record more sunshine e. g. — Nelson (North-eastern district), Napier (near southern limit of East Cape district) and Lincoln (E. of Eastern district). Some of the western districts, on the other hand, record less bright sunshine. The following table details the somewhat scanty information available as to sunshine throughout New Zealand: —

year	Auckland		Gisborne		Napier		Moumahake[1])		Wellington		Lincoln		Nelson	
	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.	Hr.	Min.
1907			1939	20	2161	35	1897	34	1853	53	2133	53		
1908			2259	20	2806	42	2001	40	2009	3	2185	11		
1909			1965	40	2203	20	1856	17	2223	31	2112	9	2562	58
1910	1775	45	2293	4	2530	47	1869	15	2157	3	2083	42	2571	34
1911	1975	30	2147	20	2406	56	1692	25	2276	37	2326	0	2506	56
1912	1834	21	1750	9	2451	25	1906	55	1953	17	1782	7[2]	2227	15
1913	1945	20	2091	35	2626	5	2214	20	1973	39	1950	23[2]	2107	10
Average	1882	44	2063	47	2519	24	1919	46	2063	52	2081	55	2395	11

5. Wind.

Wind, especially in certain botanical districts, is a most important ecological factor. Generally speaking its effect becomes more intense the further S. one proceeds or the higher one ascends. It is also of great moment on the coast especially on the W. and on small islands.

The westerly winds of the South Island are of special moment. Striking the western mountain wall, the wind loses its moisture in passing over the high lands and descends on the E. as a hot wind sweeping through the river valleys and over the gravel plains, raising transpiration to its maximum.

The S.W. wind is also of high importance, sometimes bringing with it cold squalls of a subantarctic character or even a heavy downpour, while, at other times, rain is wanting but a furious gale rages for one or two days at a time. The change from N.W. to S.W. on the E. is quite sudden; the temperature drops many degrees and conditions approximating to those of midwinter may occur in the middle of summer. Obviously such sudden changes are of great physiological importance.

The average velocity of the wind in the following tables is from records of the Robinson anemometer in kilometers per day.

1) Egmont-Wanganui district.

2) Incomplete, 13 days no record kept.

Jan.	Feb.	Mar.	Ap.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Auckland											
440	290	285	232	259	254	277	278	290	315	334	301
Wellington											
490	437	456	460	414	387	371	387	452	559	530	515
Hokitika											
230	216	211	214	198	187	174	192	229	272	243	228
Lincoln											
315	292	380	256	213	192	186	214	269	309	315	301

	Auckland (11 years)	Wellington (16 years)	Hokitika (16 years)	Lincoln (13 years)
Average per day	288	451	216	262
Maximum velocity for one day	1558	1920	1108	1547

6. Details regarding the botanical districts.

1. *The Kermadec district.*

According to OLIVER (1909: 124—126), the climate is mild and equable with many rainy days, considerable precipitation, much wind, especially in the winter, and a constantly humid atmosphere.

The absolute maximum and minimum temperatures during the period of OLIVER's visit were 31.7° (January) and 8.7° (August) and the mean maximum and minimum 21.7° and 15.7° respectively. The rainfall from February to October inclusive was 172 cm and the number of rainy days 176. The average velocity of the wind was 328 km a day. The above figures however are for only one year so that no true comparison can be made with the other districts as given below.

2. *The Three Kings district.*

No meteorological data are available.

3. *The North Auckland district.*

a. Northern portion.

The climate is the warmest and least disturbed of the main islands. In summer, easterly breezes of a subtropical nature prevail. Winter is decidedly the rainy season. The mean temperature is 16.2° C., the mean of the absolute maxima of the year being 4.5° above this and the mean of the minima 4.1° below, showing a mean daily range during the year of only 8.6°. Frosts occur inland at times but they are extremely light. Snow is altogether absent. The mean annual rainfall is about 151 cm, its distribution being as follows: —spring 22.7 p. c.; summer 13.1 p. c.; autumn 29.4 p. c.; winter 34.6 p. c.

b. Southern portion.

The rainfall is lighter than that of the northern portion of the district the annual average being 127 cm. Cumulus clouds frequently gather on summer afternoons but generally disperse without rain, but the total sunshine is apparently diminished. The climate is mild and humid; the mean absolute daily range of temperature is 7.4°; the mean of the maxima is 3.6° above and the mean of the minima 3.8° below the average mean of 15.2° C. The rainfall is distributed as follows: — spring 24.1 p. c.; summer 18.7 p. c.; autumn 24.9 p. c.; winter 32.3 p. c.

4. *The South Auckland district.*

a. The Waikato sub-district.

The range of temperature, especially in summer, is greater than in the North Auckland district, January having a mean maximum of 24.1° and a mean minimum of 11.4°. The mean annual temperature is 14.2°, the mean maximum 19.7°, the mean minimum 8.7° and the mean daily range 11°. The winds are possibly more steady and less variable in direction than in the surrounding districts. Dews are heavy but frosts are not often experienced until at the junction with the Volcanic Plateau. The average annual rainfall is 140 cm distributed as follows: — spring 26.8 p. c.; summer 17.1 p. c.; autumn 25.2 p. c.; winter 30.9 p. c.

b. The Thames sub-district.

The mountainous nature of the district leads to local climatic differences. The rain is easterly rather than westerly. Taking the Waihi returns as fairly typical, there is a mean annual temperature of 12.9°; the mean maximum is 18.4, the mean minimum 7.5° and the mean daily range 10.9°. Frost occurs during winter on the higher summits. The total mean annual rainfall is 165 cm distributed as follows: — spring 24.2 p. c.; summer 18.3 p. c.; autumn 26.8 p. c.; winter 30.7 p. c.

5. *The Volcanic Plateau district.*

This has a climate far from uniform, extending as it does from the coast to the summit of the central volcanoes. Taking Rotorua (altitude 282 m) as typical of a good deal of the area, the mean annual temperature is 12.6°, the mean maximum 18.4° and the mean minimum 6.7°. Frosts are frequent in winter, except near the sea, — 6° being often registered at Rotorua, while in the subalpine and alpine belts frost may occur at all times of the year. At from 900 m to 1200 m altitude, snow lies in winter for a few days, but near the glaciers of Ruapehu there are perpetual snow-fields. The mean annual rainfall, combining Rotorua and Taupo stations, is 137 cm distributed as follows: — spring 24.9 p. c.; summer 22 p. c.; autumn 25 p. c.; winter 28.1 p. c.

6. *The East Cape district.*

Owing to the hilly nature of the area there is much modification of climate. The littoral is sheltered from westerly winds. E. to south-easterly winds in cyclones bring heavy rains and occasional floods, 20 cm falling in a day. The mean temperature is 14.4°, the mean maximum 19.2° and the mean minimum 9.7°, showing an absolute mean daily range of 9.5° for the year. Frost and snow are frequent at the higher levels. The mean annual rainfall is 108 cm and its distribution as follows: — spring 20.1 p. c.; summer 19.5 p. c.; autumn 29.7 p. c.; winter 30.7 p. c.

7. *The Egmont-Wanganui district.*

This has a westerly aspect and most of the rain comes from that direction. Mt. Egmont, and the hilly parts inland, have a heavier rainfall than the lowlands. The temperature, taking the average of a number of stations, gives a mean of 13.2°, a mean maximum of 18.4°, a mean minimum of 8.3° and a mean daily range of 10.1°. Frost is of moment only at the higher altitudes. The westerly winds, carrying salt spray inland for several kilometres, are antagonistic to many species of plants. The mean annual rainfall is 118 cm and its distribution is as follows: — spring 25.1 p. c.; summer 21.8 p. c.; autumn 25.4 p. c.; winter 27.7 p. c.

8. *The Ruahine-Cook district.* (*Excluding the Marlborough Sounds.*)

Much of this district has a climate considerably affected by the proximity of Cook Strait. The predominant weather is westerly but not infrequently it falls under the influence of subtropical disturbances. The Dividing Range distinctly influences the climate, so that the plain on its eastern side receives less rain than other parts of the district. The mean annual temperature is 13.2°, the mean maximum 17.5°, the mean minimum 8.9° and the mean daily range 8.6°. High winds are a characteristic feature. Frost and snow are frequent in the subalpine and alpine belts. The mean annual rainfall is 108 cm and distributed as follows: — spring 22.6 p. c.; summer 20.8 p. c.; autumn 26.8 p. c.; winter 29.8 p. c.

9. *The North-eastern district.*

This extremely mountainous district is sheltered from the prevailing westerly winds, and has a dry and semi-continental climate, subject however to heavy rain at times from the E. The lower part of the Awatere valley has the second lowest rainfall in the New Zealand region. The mean temperature, derived from Nelson and Hanmer records, is 12.7° with the mean maximum 5° higher and the mean minimum 5° lower. Frost is common, except near the coast-line and as low as —12° has been recorded. Snow is abundant in winter on the high mountains. The mean annual rainfall is 92 cm distributed as follows: — spring 25 p. c.; summer 23.3 p. c.; autumn 26 p. c.; winter 26.7 p. c.

10. *The Eastern district.*

This district has also a semi-continental climate. The hot wind, already described, though not peculiar to the district, is an important climatic feature. Extremes of climate constantly occur and a sudden shift of the wind to a southerly direction brings a rapid decline in temperature. These southwesters are frequently accountable for heavy showers and thunder storms, but the most generous rains are from the S. E. The mean temperature is 11.5°, the mean maximum 16.4° and the mean minimum 6.6°. Frost is frequent and more severe close to the shore-line than in any other part of New Zealand at that altitude, — 8° not being uncommon. Also snow may lie for several days at sea-level in winter, but this is not a common occurrence. Perpetual snow only lies in patches on the highest peaks. The mean rainfall is 65 cm distributed thus: — spring 24.3 p. c.; summer 23.8 p. c.; autumn 25.9 p. c.; winter 26 p. c. Were records available for the high mountains and western part of the district, the total rainfall would be considerably increased.

11. *The North-western district.*

This possesses a humid climate with a heavy rainfall. It is fully open to the prevailing westerly winds and while those from the N. W. bring rain, as they change to the S. the weather clears while S. E. winds occasionally are of a foehn-like character. Frost and snow are abundant in the mountains in winter and to some extent at all seasons, but of little moment at sea-level. The mean rainfall is 188 cm distributed as follows: — spring 25 p. c.; summer 22.6 p. c.; autumn 26.2 p. c.; winter 26.2 p. c.

12. *The Western district.*

This district has a still heavier rainfall than the North-western, otherwise the climatic conditions are very similar. The snow-fall is extremely heavy on the high mountains, so that glaciers of great size descend to remarkably low altitudes both on the E. and W. of the Southern Alps. The sky notwithstanding the copious downpour is frequently clear and sunshine more abundant than could be anticipated, e. g. 1720 hours in 1913 but that year was exceptionally fine. April (32 cm) and October (36 cm) are the months of greatest rainfall. The mean annual rainfall is 317 cm distributed as follows: — spring 27.7 p. c.; summer 23.3 p. c.; autumn 26.3 p. c.; winter 22.7 p. c.

13. *The Fiord district.*

This district has the maximum rainfall and the greatest number of rainy days in the New Zealand region. Frost and snow, though frequent in the mountains and occurring at all seasons are probably of little moment at sea-level. Taking the few isolated stations for which records are available there is a mean of 413 cm distributed as follows: — spring 24.8 p. c.; summer 22.4 p.c.; autumn 29.5 p. c.; winter 23.3 p. c.

14. *The North Otago district.*

This district is the dryest in the region. In summer, the days are frequently hot, but the nights chilly, except when the N. W. foehn blows. In winter, the nights are generally frosty, but snow rarely lies beyond a day or two except above the subalpine belt. Exaggerated reports of temperatures are periodically received from the interior of this district, but are discounted by the presence of introduced plants which can tolerate but little frost. The average rainfall for the district is 45 cm. Alexandra South, in the dryest part, had a rainfall of 24 cm on 66 days in 1906 and a maximum of 35 cm on 67 days in 1900. Judging from the vegetation, the rainfall increases considerably from the lower limit of the subalpine belt upwards, but even there it is less than on the dry mountains of New Zealand in general.

15. *The South Otago district.*

Owing to the frequency of cold rain-bearing S. W. winds with cloudy sky and the comparatively low summer temperature, the climate of this area approximates more to the subantarctic type than that of any other of the mainland botanical divisions, except the Fiord district. At the same time, it must be pointed out that there is much bright sunshine and cloudless sky, as in New Zealand generally. The N. W. wind is dry, its moisture having been lost in passing over the Fiord district. High winds are frequent and at times sweep over the open Southland plain with fury. Much of the district is mountainous with winter snow of comparatively long duration. Snow at sea-level too is not uncommon, but frosts at that altitude are less severe than on the coast of the Eastern district. The mean temperature is 10° and the mean maximum and minimum respectively 15.3° and 4.6°. The average rainfall is 117 cm which is distributed as follows: — spring 26.3 p. c.; summer 24.6 p. c.; autumn 27.1 p. c. und winter 20 p. c.

16. *The Stewart district.*

Here the subantarctic character of the climate is still more marked, especially in the S. W. and on the open mountains. The number of rainy days is excessive, Halfmoon Bay on the E., the driest part of Stewart Island, having a yearly average of 241 cm for a term of 14 years with a maximum of 283 cm and a minimum of 223 cm. The climate is remarkably mild, frost being almost absent on the E. coast, while snow is generally confined to the mountains. Wind is frequent and often exceedingly violent, except on sheltered parts of the E. coast. The rainfall of the E. for 10 years averages 161 cm and its distribution is as follows: — spring 26.7 p. c.; summer 22.5 p. c.; autumn 27.9 p. c.; winter 22.9 p. c.

17. *The Chatham district.*

The climate is purely maritime. As is usually the case with small islands of low altitude, there is a comparatively low rainfall, but the number of rainy days, especially in winter, is excessive. The winds are generally strong and are mostly westerly with a southerly tendency. The mean temperature is 10°, the mean maximum nearly 4° more and the mean minimum 2° less. Frosts are extremely light and rare while snow is seldom seen. The distribution of the rainfall is as follows: — spring 21.5 p. c.; summer 22.3 p. c.; autumn 26.7 p. c.; winter 29.5 p. c.

18. *The Subantarctic province.*

The question of climate for the province in general receives consideration in Section IV, Chapter III. Here only those parts are dealt with for which meteorological statistics are available.

a. The Campbell district.

Here cloudy and squally weather predominates with "brave westerly winds of the roaring forties" with frequent changes to the S. W., these bringing hail, sleet or snow. The mean annual temperature for 1905—06 was 7° with a mean daily range of 5.3°. The summer temperature is low, averaging 9.5° and the mean winter temperature 4.3°. Judging from the plant-life and from the observations of COCKAYNE in midwinter, frost is less severe than in certain parts of the South Island of New Zealand. The rainfall at Tucker Cove in 1905 was 136.7 cm on 260 days and in 1906 143.5 cm on 280 days.

b. Macquarie Island.

The climate of Macquarie Island is of the most marked subantarctic type. Extremes of heat and cold are altogether wanting, the absolute maximum during the summer months very rarely indeed reaching 10°, while the absolute minimum seldom falls below —1°. Taking the year 1913, during June the temperature ranged between 6.1° and —5°, this latter an exceptionally low record, and there were only 11 frosty days in all. In December of the same year, the absolute maximum was 11.6° and the absolute minimum 5°, while there were 12 days in which the temperature did not reach 6.7°. No records are available regarding the amount of rainfall, but, as for the subantarctic climate in general, there are few days without more or less precipitation. Wind is a most important factor. Frequently it blows with extreme violence, while but one or two calm days occur in any one mouth. This stormy weather is clearly indicated by the range in barometric pressure which had a maximum of 775 mm on June 23rd, 1913 and a minimum of 708 mm on April 20th, 1913. The wind blows most frequently from the W; N. and N. W. winds are also common; S. W. are fairly frequent but easterlies are rare.

Part II.

The Vegetation of Primitive New Zealand.

Section I.

The Vegetation of the Sea-coast.

Chapter I. General Observations on the Coastal Vegetation.

1. Brief Account of the Coast-line.

The coast-line of New Zealand offers most diversified stations for plant-life. Not only does it face the actual ocean for a distance of more than 4800 km, but it extends far inland, in many places, either as shallow estuaries, tidal rivers, drowned valleys or fiords of profound depth. The actual coast itself may be quite low, more or less hilly, or high mountains may rise precipitously from the water's edge. There are vast stretches of dunes; long lines of cliffs; sandy, muddy, gravelly or shingly shores; low-lying flats exposed to inundation by brackish water; tidal rivers which leave portions of the muddy floor bare at low tide and rocks extending out into the sea. Lying off certain parts of the coast at various distances are islands differing greatly in size. These offer less complex ecological conditions than does the mainland and, in many cases, their plant-covering is quite virgin. Finally, there are ancient coast-lines where certain maritime species still exist.

2. Statistics regarding the families, genera and species.

The coastal species fall into the two categories of those confined, or virtually so, to the shore-line, or its immediate neighbourhood, and those which belong equally to inland formations, some of this latter class being sufficiently abundant to affect, in parts, the coastal landscape.

The true maritime pteridophytes and spermophytes number 189 species belonging to 54 families and 107 genera. One hundred and forty seven ot the above are con ined to the actual coast, or thereabouts, while 42 occur inland to some limited extent, but, with few exceptions, these latter are negligible so far as the general inland vegetation is concerned. Regarding general distribution 130 or almost 70 p. c. are endemic, 40 Australian, 13 Subantarctic South American and 11[1]) Cosmopolitan, or nearly so. The larger families and genera of the coast and the number of species in each are as follows: — (Families) *Compositae*, 24; *Scrophulariaceae*, 19; *Gramineae*, 18; *Chenopodiaceae*, 10; *Cyperaceae*, 9; *Umbelliferae*, 8; *Filices* and *Rubiaceae*, 7; *Potamogetonaceae*, *Cruciferae* and *Pittosporaceae*, 6 and *Aizoaceae* and *Araliaceae*, 4; (Genera) *Veronica*, 14; *Olearia*, 8; *Coprosma* and *Senecio*, 7; *Pittosporum*, 6 and *Carex* and *Lepidium*, 5.

The following 9 families and 36 genera are with few exceptions coastal in New Zealand; they contain 44 species thus leaving 145 species or 76 p. c. of the coastal species related to inland plants[2]): — (Families) *Nyctaginaceae*, *Aizoaceae*, *Corynocarpaceae**, *Tiliaceae*, *Primulaceae*, *Sapotaceae*, *Myoporaceae**, *Cucurbitaceae* and *Goodeniaceae**, — (Genera) *Ruppia**, *Zannichellia**, *Zostera* (Potamoget.), *Spinifex*, *Atropis*, *Bromus** (Gramin.), *Hydatella* (Centrolep.), *Leptocarpus** (Restiac.), *Macropiper** (Piperac.), *Salicornia*, *Rhagodia**, *Suaeda*, *Salsola**[3]) (Chenopod.), *Pisonia* (Nyctaginac.), *Mesembryanthemum*, *Tetragonia* (Aizoac.), *Spergularia* (Caryophyll.), *Capsella* (Crucif.), *Clianthus** (Legum.), *Euphorbia* (Euphorbiac.), *Corynocarpus** (Corynocarp.), *Dodonaea** (Sapindac.), *Entelea* (Tiliac.), *Hibiscus* (Malvac.), *Stilbocarpa*, *Meryta* (Araliac.), *Samolus* (Primulac.), *Sideroxylon* (Sapotac.), *Eryngium*, *Apium** (Umbell.), *Ipomaea* (Convol.), *Avicennia* (Verbenac.), *Mimulus* (Scroph.), *Sicyos* (Cucurbit.), *Selliera** (Goodeniac.) and *Sonchus*[4]) (Compos.).

With regard to the coastal-inland species it is hardly possible to supply detailed statistics. According as forest, steppe or heath approaches high-water mark so will a considerable percentage of its species be present. All depends upon the climatic and edaphic conditions of the locality, and in many instances, except close to the water's edge, the special coastal ecological factors may be absent. But, on the other hand, many inland plants tolerate fairly intense maritime conditions, so that more than 100 species thrive on one part or other of the coast-line. The following, for example, are, in places, sufficiently abundant to be of prime physiognomic importance: *Freycinetia Banksii*, *Arundo conspicua*, *Mariscus ustulatus*, *Cladium Sinclairii*. *C. junceum*, *Phormium tenax*, *P. Cookianum*, *Urtica ferox*, *Muehlenbeckia australis*, *M. com-*

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1) It is well to explain that the figures given here and elsewhere in this book, are to some extent based on personal judgement. No two observers would be likely to agree as to whether certain species should be considered coastal or not. Also species of wide distribution are not included in the Australian or South American estimates, notwithstanding their occurrence in those regions, and, again, "wide distribution", "cosmopolitan" &c. are quite loose terms. Finally, certain Australian species are likewise South American and such are included in both categories.

2) An asterisk denotes that the species though nearly always coastal does occasionally occur inland. Should a species occur at 100 m or more altitude on a small island, or a hill adjacent to the coast, it is here considered coastal.

3) Perhaps not indigenous.

4) The opinion is here held that *Sonchus littoralis* (T. KIRK) COCKAYNE is the only indigenous species of the genus.

plexa, *Leptospermum scoparium*, *L. ericoides*, *Metrosideros lucida*, *M. scandens*, *Griselinia lucida*, *Dracophyllum longifolium*, *Veronica salicifolia*, *Olearia insignis*, *Cassinia fulvida*, *C. Vauvilliersii* and *Gnaphalium trinerve*.

3. Changes in species according to latitude.

The coast-line, from the Three Kings' Islands in the N. to the southernmost part of Stewart Island in the S., extends through 13° of latitude from about 34° 20′ S. to 47° 20′ S., or if comparisons be drawn from the northern hemisphere, from the mouth of the Loire, in France, to Rabat on the W. coast of Morocco, or from the N. of the E. coast of New Brunswick, in North America, to the extreme S. of North Carolina. Since, in coastal plant-distribution, variation in altitude does not come into consideration, the effect of change in latitude is more clearly reflected in the distribution of the coastal element than in that of any other section of the flora. The general statistics regarding coastal distribution which follow may be noted in this respect.

The Northern, Central and Southern botanical provinces contain respectively 120, 118 and 120 coastal species with 29, 14 and 41 species peculiar to each. Only 4 of the special northern species occur throughout the province, leaving the Three Kings botanical district[1]) out of consideration, while, as for the remainder, 6 species are confined to the Three Kings; 3 occur only on the North Cape Promontory; 7 do not extend beyond about lat. 35° 30′ S., and, of these latter, 4 have been recorded each from one locality only, 7 do not occur S. of Manakau Harbour, but none of these are wide-spread while 3 are of most restricted distribution; finally 2 are confined to the Thames sub-district.

All the species peculiar to the Central province are either of local or most restricted distribution and none occur in the Egmont-Wanganui district. Six are confined to the East Cape district, 4 to the E. and S. of the North Island portion of the Ruahine-Cook district, 2 reach the Marlborough Sounds and the remaining 2 are of little moment.

The 41 species peculiar to the Southern province are, with but few exceptions, of a subantarctic or subalpine type and have their headquarters in the S. and S. W., no fewer than 33 being restricted thereto of which 29 occur in Stewart Island, 10 being restricted to that district.

Although 56 species are common to the three botanical provinces only 40 (21 p. c.) of the coastal flora, all halophytes or psammophytes except 1, extend from the extreme N. of the North Island to the N. shore of Foveaux Strait, while but 30 of these (16 p. c.) reach Stewart Island and 10 (5 p. c.) the Three Kings. Of the remaining 16 species 11 occur throughout the Northern and Central provinces, but do not pass beyond the N. part of the Southern;

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1) The total number of coastal species recorded by CHEESEMAN for these islands is only 28. This small number may be accounted for in part by the precipitous nature of the coast-line and the absence of dune and salt-meadow.

2 more extend almost from the N. of the North Island to Foveaux Strait, and of 3 with their northern limit in the S. of the Northern province 2 reach N. Otago and 1 Foveaux Strait.

The distribution of the remaining coastal species is as follows: Thirty-four are confined to the Northern and Central provinces, 13 of which occur throughout or nearly so, 16 do not pass beyond the N. of the Central province and the remaining 5 are of restricted distribution. Fourteen species are confined to the Central and Southern provinces but only 1 occurs throughout. Four species which are common in Stewart Island extend just across Cook Strait by way of the west coast of the South Island, 1 only gains northern Marlborough, 3 extend from the East Cape to the centre of the Southern province and 1 occurs from southern Wellington to Banks Peninsula on the east.

4. General Ecology of the Coastal Vegetation.

The special conditions to which coastal plants are subject consist of a greater amount of salt in the soil than ordinary land-plants can tolerate, exposure to salt-laden winds which are frequently both violent and of long duration and, in some stations, strong insolation. The coastal climate is generally uniform; frost is absent in the Northern botanical province and but trifling in the Central while in the Southern too it is of little moment, except on the coast of the Canterbury Plain where it may reach — 7° C. Excess of salt in the soil and salt-laden winds are by far the more important of the above factors, and on such depend the characteristic coastal formations and the adaptations or capabilities of the species. At the same time, a salt soil is frequently absent, as on dune-areas where the power to tolerate salt winds or indeed violent wind in general is a matter of prime moment. From the above it follows that ground subject to flooding with brackish water or to frequent wetting by sea-spray is the chief home of halophytes, and that other formations will be governed first of all by position with regard to the prevailing wind and its frequency. The composition of coastal shrub associations is distinctly in harmony with the wind-factor. At the base of the Bluff Hill, Southland, at the spot where the frequent S. W. wind strikes with full force, the mixed shrub association of a calmer atmosphere is either absent or replaced by a pure scrub of the xerophytic *Olearia angustifolia*. So too at the water's edge of the inlets of Stewart Island *Senecio rotundifolius* replaces fern-forest, but is itself replaced on the more exposed headlands by *Leptospermum scoparium* (Fig. 1).

The rainfall strongly influences the general vegetation of the shore-line since the number of rainy days determines the presence or absence of forest. Where the maximum of wet days occurs, as on the W. coast of the South Island, rain-forest comes almost to the water's edge. Dune and salt-meadow, special edaphic formations, are but little affected by rain-fall and bear their characteristic plants equally in the wettest or dryest districts. The semi-subantarctic climate of the South Otago, Fiord and Stewart districts favours plants with subalpine adaptations so that there are not only such amongst the true coastal species, but actual subalpine species rare or absent inland except in the high mountains, may occur close to the sea.

The winter cold of the Canterbury Plain offers an impassable barrier to certain northern plants[1]) which have in consequence their southern limit on the E. on Banks Peninsula, while on the W. the rain-forest climate offers an obstacle of another description.

The plants themselves play no small part in their own distribution so far as they supply shelter and make soil; trees, shrubs and plants of the tussock-form supplying the former and certain coastal ferns and spermophytes the latter in the form of raw humus or peat. Other factors of local importance receive mention when dealing with the formations.

Chapter II.

The leading Physiognomic Plants and their Growth-forms.

1. Dune Plants.

a. *Scirpus frondosus* Bank et Sol. (*Cyperac.*) *Pingao.*

S. frondosus is a stout, far-spreading, sand-binding sedge. The rhizome is about 1.7 cm in diam., somewhat woody, much-branching, covered with old leaf-sheaths, and many metres long. At first, it creeps close to the surface, but is soon buried and forms eventually a complete tangle of rope-like stems in the sand. The leaves are in bunches lightly bound together at their bases by the sheaths so that a bulbous mass about 2.5 cm in diam. is formed, but they gradually open out, curving somewhat inwards. The sheath is about 10 cm long by 5 cm broad at the base, moderately thick in the centre, translucent and membranous at the margin, and sticky everywhere with a resinous exudation which helps to bind the sheaths together. The blade, 60 cm long by 7 mm broad, tapers gradually to a long trigonous point; it is thick, coriaceous, stiff but flexible, concave on the upper and convex on the under surface so that the leaves fit one into the other. The colour is a rather dark glossy green near the base and on the under surface, but the upper surface, especially above, is frequently orange-coloured or reddish, though the leaves, as a whole, viewed from a distance appear yellow. The branches are given off so closely that the separate leaf-bunches touch making semi-tussocks or continuous lines.

The inflorescence, 10—20 cm long, consists of clusters of densely-crowded, sessile, reddish-brown, globose spikelets spirally arranged round the stem, each cluster subtended by a linear leaf-like bract.

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1) *Mariscus ustulatus, Macropiper excelsum, Rhagodia nutans, Dodonaea viscosa, Corynocarpus laevigatus.* Several other species behave similarly but they are not specially coastal.

The roots are very long, but little branched and descend deeply.

Juvenile plants growing in hollows show little trace of the subsequent rhizome development, which depends upon a constant sand-burial.

S. frondosus belongs to an endemic sub-genus (*Desmoschoenus*) thus affording an excellent example of a very special adaptation developed in an isolated region. It occurs throughout both the main Islands, Stewart Island and the Chathams.

b. Spinifex hirsutus Labill. (*Gramin.*). (Plate V, Fig. 6).

S. hirsutus is a powerful sand-binding grass. The creeping stem is extremely long, much-branching, smooth, hard, flexible and woody. At first it creeps on the surface of the sand, rooting at the nodes, the internodes about 12 cm long. It is soon covered by the advancing sand, though the apex may again emerge to the light, but usually it is only the branches or leafy shoots which do so, these latter frequently ascending through the sand from a stem 50 cm below. The leaf consists of blade and sheath. A normal blade is 47 cm long by 10 mm broad and tapers to a fine, but usually dead, point. The texture is thick and coriaceous, but flexible; both surfaces are thickly covered with adpressed silky hairs. The sheath is about 11.5 cm long, pale, thick and fleshy. Near the apex of a surface-creeping rhizome the leaves are smaller with shorter blades and broader sheaths. The roots are numerous, slender, wiry and often more than 1 m long. The flowers are dioecious. The male spikes are numerous, about 8 cm long and form a terminal umbel with sometimes 2—3 spikes making a cluster below. The female inflorescence is a large globose head, sometimes 30 cm in diam., composed of 1—2-flowered spikelets each at the base of a long, sharp-pointed, radially spreading spine some 12.5 cm long. Pollination occurs from the middle of November to the middle of December.

S. hirsutus is confined to the Northern, Central and N. of the Southern botanical provinces, its southern limit being about lat. 43°; it is also indigenous in Australia and New Caledonia.

c. Carex pumila Thunb. (*Cyperac.*).

C. pumila is a small grass-like sedge having a long, slender rhizome some 3 mm in diam. which gives off, at intervals, bunches of 4—6 fully developed leaves. The leaf-blade is thick, coriaceous, flexible, 30 cm long more or less, glaucous-green and tapers gradually to a fine point; its upper surface is deeply concave through the curving margins. In position, the leaf is erect towards the base, but above it curves so that the apex almost touches the ground. The roots are long and slender. The culms are short, stout and about 15 cm tall. The utricle is large, thick, turgid and about 7 mm long.

The species is common in the North, South, Stewart and Chatham Islands. It occurs also in Australia, E. Asia, and temperate South America.

d. Coprosma acerosa A. Cunn. (*Rubiac.*).

C. acerosa has the divaricating shrub-form, but more depressed than is usual with that class, making flattened orange-coloured or reddish open cushions or thick mats of interlacing twigs. The main stem is flexible, rope-like, about 1.8 cm in diam., prostrate, covered with thick brown bark, and either buried in the sand or quite hidden by the interlacing twigs. These latter, forming the cushion, are wiry, flexuous and flexible; the branching is at right angles or thereabouts and frequently only from the flanks of the stem. The leaves in opposite pairs on much reduced branchlets are pressed closely to the stem, the naked spaces equalling those covered by the leaves. These latter are linear, 7 mm long, thick, coriaceous, pale or yellowish green. The roots are extremely long, but short adventitious ones are frequent on the peripheral shoots. The flowers are dioecious. The drupe is globose, fleshy, 7 mm long more or less, translucent and white stained with pale blue.

The species is endemic; it occurs throughout the region except the Kermadec and Subantarctic botanical provinces and is strictly coastal.

e. The dune-species of Cassinia (*Compos.*).

The three dune-species, (*C. leptophylla*, *C. retorta* and *C. fulvida*), are identical in form and differ only in colour of tomentum and slight distinctions of leaf-form and inflorescence. They are erect bushy ericoid shrubs from 1 m or less, to 2 m or even more, high. The main stems arc few, naked, not much branched below, but above branching abundantly into slender leafy twigs which finally give off, at a narrow angle, flexible, straight branchlets covered with tomentum, either white (*C. retorta*), greyish (*C. leptophylla*) or yellow (*C. fulvida*). The ultimate shoots form close masses. The leaves are linear-obovate (*C. retorta*), or linear to linear-spathulate, about 3—4 mm long, moderately thick and coriaceous, abundantly tomentose beneath but shining-green above. *C. fulvida* has glutinous branches and the tomentum on leaf and stem gives the shrub an almost golden colour. The flower-heads are numerous and in terminal corymbs. The inner involucral bracts have white, radiating tips and so render the inflorescence conspicuous.

All the species of *Cassinia* are endemic. *C. retorta* is strictly coastal and confined to the Northern botanical province. *C. fulvida* and *C. leptophylla* extend inland, the former ascending into the montane zone and occurring both in the Central and Southern botanical provinces, but the latter is virtually confined to the Central province.

2. Salt-swamp plants.

a. Leptocarpus simplex A. Rich. (*Restionac.*) *Oioi*; *Yellow Rush.*

L. simplex forms dense tussocks of erect, slender, stiff, wiry but flexible rush-like stems which vary in harmony with the intensity of the illumination from dull-green to bright red-orange. There is a rather stout rhizome, which, at times, growing erect and branching may form a trunk 20 cm high. The leaves are represented by short, blackish, sheathing scales which clasping the terete stem at distances of 2.5—10 cm give it a characteristic appearance. The roots are wiry and of medium length. The flowers are dioecious; the male inflorescence is paniculate with numerous reddish-brown spikelets, while the female is compacted into rounded glomerules alternating along the stem.

L. simplex is endemic and common along the coast in all parts except the Kermadec and Subantarctic botanical provinces. It occurs inland near hot springs on the Volcanic Plateau, as also on the shores of Lake Manapouri and along the route of the ancient strait in Stewart Island.

b. Juncus maritimus Lam. var. *australiensis* Buchen. (*Juncac.*).

This plant, of the ordinary rush-form, makes dense tussocks about 90 cm high and 50 cm in diam. at the base. The dark-green, glossy terete stems and leaves taper gradually to a pungent but frequently dead brown point.

The same variety occurs in Australia. In New Zealand, it is common on the coast from the N. of Auckland to South Canterbury. Inland, it grows near certain hot springs on the Volcanic Plateau.

c. Plagianthus divaricatus Forst. (*Malvac.*).

P. divaricatus is a dark-coloured almost deciduous shrub of the divaricating growth-form. There is a stout main stem 5.7 cm in diam. which gives off several branches passing upwards and outwards, finally branching abundantly into short, wiry twigs given off at a wide angle and closely interlacing; the whole forms a dense, compact, elastic, rounded mass, a flat mat or even an open cushion. According to the degree of exposure to wind, the periphery may be wiry and close or twiggy and open. The naked interior stems are 3 cm thick or more, twisted, curved and liane-like in appearance. The leaves on much-reduced branchlets, are very small, linear to linear-obovate, 7 mm long and slightly coriaceous. The flowers are very small, pale yellow or whitish edged with purple, honey-scented and produced from September to October. According to CHEESEMAN (1906: 76) they are generally unisexual, but Miss CROSS (1910: 553) states they are hermaphrodite but strongly protandrous. The roots are long, stout and descend deeply or spread laterally.

The species is endemic and occurs in all the botanical provinces except the Kermadec and Subantarctic.

d. Avicennia officinalis L. (*Verbenac.*) *Manawa*; *Mangrove.*

A. officinalis is a shrub or small tree varying in height from 60 cm to 9 m, or even more. As a tree, it has a stout, but usually short, main trunk from which a few short primary branches pass off, spreading outwards and branching some 4 or 5 times so as to form a round-headed fairly dense crown. The bark is rough, grey and much furrowed. The ultimate and subultimate twigs are brittle, slender, much curved and marked with old leaf-scars.

The leaves are ovate to ovate-lanceolate, 5—10 cm long, thick, coriaceous, dark-green, rather glossy and with yellow midribs and veins. Beneath they are covered with hoary pubescence. They are frequently placed more or less vertically. The roots extend for a great distance laterally and this is emphasised by the hundreds of erect branches, (pneumatophores), which project out of the muddy substratum. These erect roots are from 20—30 cm long on an average; they are straight and taper from the base upwards to a blunt apex.

The inflorescence consists of small heads of 5—8 flowers each about 8 mm in diam. The fruit, which is ready to fall by the beginning of January, consists of a capsule some 4.2 cm long by 2.8 cm broad and 1 cm thick; the pericarp is brown and leathery but thin enough for the penetration of sufficient light for the formation of chlorophyll. The embryo, which has no resting-period, emerges early from the seed-coat, so that by the time the fruit is ripe, it completely fills the cavity. At this stage, the embryo consists of the two thick, fleshy cotyledons folded longitudinally, the outer, which is dark-green on its upper surface tightly enclosing the inner, and the hypocotyl which is about 10 mm long slightly projecting, while the much shorter epicotyl, which has two pale rudimentary leaves, is pressed close beneath the folded cotyledons. Already the hypocotyl possesses root-rudiments in the shape of small knobs surrounding the swollen apex, while above there is a ring of brownish hairs which project upwards. After falling from the tree the embryo continuing to increase in size splits the pericarp along its suture, and first one half and then the other being shed, the green embryo, its cotyledons still tightly folded and the blunt apex of the hypocotyl projecting, lies on its side in the mud, and may be washed hither and thither by the tide. As time goes on, the cotyledons open out by slow degrees, the hypocotyl lengthens and when it is about 2 cm long and the outer cotyledon is quite raised from the inner the roots are obliquely penetrating the substratum and firmly anchoring the plantlet. Growth now proceeds rapidly, especially that of the roots, but it is a considerable time before the cotyledons become fully flattened out, in fact the plant depends upon their reserve material and chlorophyll for a very considerable period. Thus a young plant with its hypocotyl 4.5 cm long, its epicotyl 3 cm long and the first two foliage-leaves 2.5 by 1.5 cm has the laminae of the cotyledons still considerably folded. Pneumatophores appear quite early, so that a root 50 cm long arising from a young plant 70 cm high, may have two of them each about 14 cm long.

A. officinalis is abundant as a mangrove in many tropical countries. In New Zealand it is confined to the Northern botanical province.

3. Trees.

a. Corynocarpus laevigata Forst. (*Corynocarpac.*); *Karaka* (Maori) *Kopi* (Moriori).

This is an exceedingly handsome small tree 6 m to 12 m high with a regular trunk 30 cm to 60 cm in diam. covered with rather thick bark rough with lenticels. The head is dense, round and glossy green. The leaves are elliptic-oblong or oblong-obovate, 7.5—20 cm long, dark-green, thick, smooth and shining. The small flowers are 4 mm in diam., hermaphrodite, greenish and borne on much-branched panicles 10—20 cm long. The drupes are more than 2.5 cm long, orange-coloured, fleshy and showy. Blooming is from August to November.

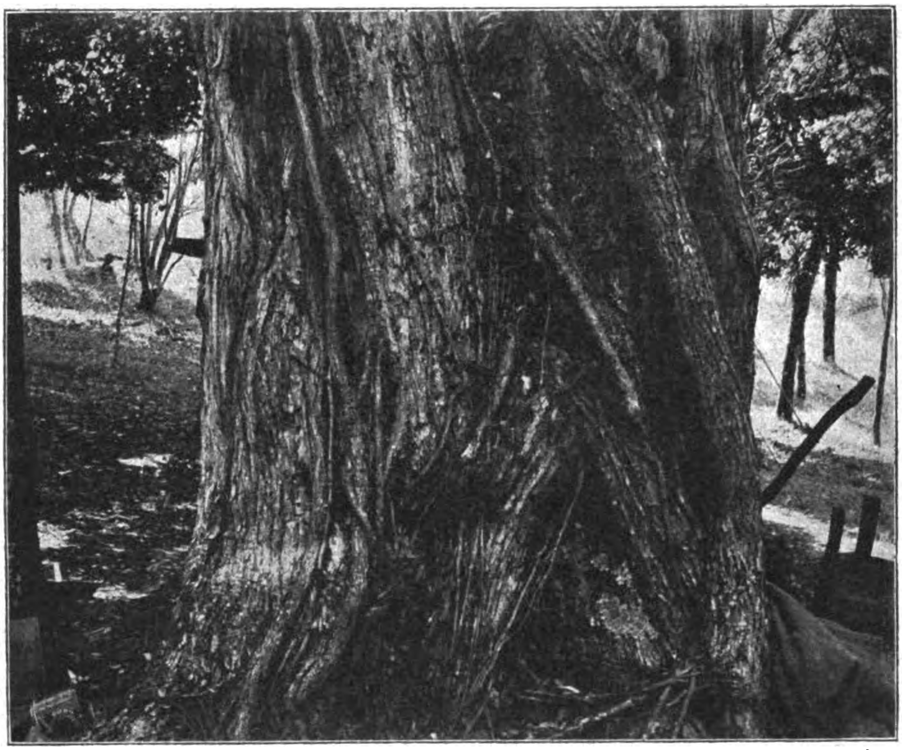

Fig. 2. Aerial roots of *Metrosideros tomentosa* descending and entering the ground. West coast of North Auckland district. Photo L. Cockayne.

The genus was long thought to be endemic and monotypic, but two exotic species are now known, one in New Caledonia and the other in the New Hebrides.

The New Zealand species extends from the Kermadec Islands to Banks Peninsula on the E. and to S. W. Nelson on the W. of the South Island, but as the tree was cultivated by the Maoris, it is not well to make dogmatic statements as to its occurring naturally in certain localities.

b. Metrosideros tomentosa A. Rich. (*Myrtac.) Pohutakawa; Christmas-tree.*

This species has various epharmonic forms which vary from a forest tree 21 m high with a trunk 60—90 cm in diam. to a small stiff-stemmed shrub

30—60 cm high, though usually taller. As a tree it is frequently of an irregular form, especially when its trunk projects more or less horizontally from some coastal cliff. At other times the trunk may be short with numerous erect trunk-like branches, issuing apparently from the ground, and in some cases growing into one another. The bark is brown, much-furrowed and wrinkled. Many adventitious roots are given off even from quite high up, and may form bunches, but those lower down often assume great dimensions and assist materially in anchoring the heavy trunk to a rock-face. The branches are massive and wide-spread and after branching several times give off finally numerous, stout, straight branchlets which bear the decussately arranged leaves and are white with a close covering of tomentum. Boughs, branchlets and leaves form a close head on the tree. The leaves vary in shape from lanceolate to broadly oblong and are 2.5—10 cm long. They are darkish green, very thick, coriaceous and clothed beneath with white tomentum, but this is absent in seedling and juvenile plants. The flowers are arranged in broad, terminal, many-flowered cymes on stout tomentose peduncles and pedicels. The calyx is also tomentose, and functions in protecting the flower-bud. The flowers are dark crimson, so that a tree in full bloom is a magnificent spectacle. The capsule is woody, and exceeds the calyx-tube; it contains numerous minute seeds of strong germinating capacity.

The shrub-form depends upon poverty of soil and exposure to wind and spray. It produces abundant foliage and may bloom when only 2.5 cm high.

The species is endemic but related to the Polynesian and Kermadec *M. villosa*. It occurs from the Three Kings Islands along the coast-line to Poverty Bay on the E. and Urenui (Taranaki) on the W. Inland it occupies cliffs &c. on the shores of many lakes on the Volcanic Plateau as also at Lake Waikaremoana (East Cape district).

c. *Myoporum laetum* Forst. f. *(Myoporac.) Ngaio.*

The Ngaio is a small tree averaging about 6 m in height with a trunk 30 cm or more in diam. which is covered with deeply furrowed bark 5 mm or so thick. The crown consists of straggling, spreading branches which finally give off numerous, stout, flexible, green, leafy twigs, viscid at their tips. The individual branch-systems frequently do not touch, so that a good deal of light can pass to the ground beneath. The leaves are lanceolate to obovate, 2.6—10 cm long, acute or acuminate, glabrous, soft, flaccid, moderately thin, darkish-green but looking paler than they really are owing to the numerous oil-glands dotted over the surface. The flowers are in clusters of 2—6 in the leaf-axils; each is about 13 mm diam., the petals are white dotted with purple The drupes are purple, oblong, 8 mm long and succulent.

When growing in a specially exposed station *M. laetum* is merely a shrub, or at times, it is altogether prostrate, so that it looks like a distinct species. It is endemic and is found generally near the coast, in all the botanical provinces except the Subantarctic. It is not native in Stewart Island although quite hardy there in cultivation.

4. The coastal Ferns.

The following three coastal ferns require notice, — *Asplenium obtusatum* Forst. f., *Blechnum durum* (Moore) C. Chr. and *B. Banksii* (Hook. f.) Mett. The first occurs in its special stations throughout the whole botanical region, excepting Macquarie Island, the second is a plant of the Southern, Chatham and Subantarctic botanical provinces, and the third extends from the North Cape to Stewart Island, but is somewhat local in its distribution. All the plants in question grow under identical conditions and are ecologically similar. They thrive best in an equable moist climate with low summer temperature and cloudy skies, and they rapidly form raw humus out of their dead parts.

Asplenium obtusatum varies much in size according to its station but is generally a rather large fern. There is a thick rhizome sometimes 30 cm long and 3.5 cm in diam. The leaves are erect, pinnate with 6—20 pairs of close-set sometimes overlapping pinnae, dark-green, linear-oblong, 5—30 cm long, and the stalk measures from 5—15 cm and is greenish to almost black, very stout and channelled above. Large examples have leaves 67 cm long by 19 cm broad. Beyond New Zealand this *Asplenium* occurs in Australia, Tasmania, Polynesia, Tristan da Cunha, the Subantarctic Islands and subantarctic South America. In New Zealand it has several very close allies of similar growth-form and occupying like stations, e. g. — *A. obliquum*, *A. scleroprium*, *A. Lyallii*, and a form of *A. flaccidum*.

Blechnum durum has a stout rhizome and, in large examples, a distinct trunk 12 cm or more high and 5 cm in diam. clothed with the old leaf-bases. The leaves which have a short stalk 2.5—5 cm long are arranged in erect, semi-erect or almost flat but recurved rosettes at the summit of the trunk or rhizome. The foliage-leaves are lanceolate, dark-green, shining and frequently about 43 cm long by 4 cm wide, though much smaller and larger dimensions are common. The pinnae are numerous and close-set the upper frequently overlapping; at first lanceolate they gradually decrease in length until the lowermost are reduced to rounded auricles. The sporophylls are shorter and narrower than the foliage-leaves and the numerous sori cover the whole under-surface.

B. Banksii, an altogether smaller fern than the two preceding, is ecologically similar to *B. durum*, but the leaves are flattened to the substratum. It appears to be confined to rocks or their immediate neighbourhood, whereas *A. obtusatum* and *B. durum* are common plants of forest near the sea and coastal moor.

Chapter III. The Biology of the Coastal Plants.

1. Growth-Forms.

a. Trees.

The coastal trees number 28; all are evergreen. Excepting 3 species[1]), none exceed 9 m in height, 6 m or less being a common stature. The tree-form is generally unsuited to coastal conditions, consequently, in exposed stations, no fewer than 24 of the trees do not develope a distinct trunk but blossom and ripen abundant fruit as shrubs merely.

The following are the growth-forms and number of species to each: Canopy-tree 11; bushy-tree 9[2]); tree-composite 4; araliad 3; and bamboo-like 1. *Paratrophis Smithii* when a shrub is of the divaricating-form[3]).

The tree-trunks, as a rule, are slender and erect, but in the latter respect some are extremely plastic, e. g. the southern tree-composites, which in response to the frequent gales, develope more or less horizontal trunks whose spread may far exceed the vertical height of the tree. *Metrosideros tomentosa*, too, growing out of a cliff-face, extends horizontally, but, when its station is ordinary level ground, the trunk is erect, though frequently very short indeed, in which case numerous erect branches function as trunks and the form is that of a gigantic shrub. *Macropiper excelsum* has frequently a much-reduced trunk, but its stems are in a category by themselves, being straight, slender, blackish-purple when young, brownish purple when mature, marked at distant intervals with leaf-scars and of a bamboo-like appearance.

The roots of the coastal trees, like those of New Zealand trees in general, often extend semi-horizontally rather than vertically downwards. Frequently they are of great length. The root-systems of the mangrove *(Avicennia officinalis)* and of *Metrosideros tomentosa* have been described in the last chapter.

The leaves of all the species are broad and, with 3 exceptions, simple; those of 7 are very large (over 20 cm long), but the remainder have leaves of medium size (5—10 cm long), except in a few species where they are smaller. Regarding texture 20 species have coriaceous leaves (6 thick), 2 rather fleshy and 6 quite thin. As for hairiness the leaves of 15 are glabrous, and of 13 hairy (tomentose 8).

b. Shrubs.

The coastal shrubs number 40 species, 21 of which are mesophytes and 19 xerophytes. Several of the species here dealt with, together with some of

1) *Corynocarpus laevigatus, Metrosideros tomentosa, Sideroxylon Novo-Zelandica.*

2) By the term "bushy-tree" is meant a low tree with short trunk more or less hidden by the abundant leafy branches. The growth-form is on the borderland between trees and shrubs. Some of the species of *Pittosporum* belong to this class.

3) CHEESEMAN (1891: 414) though he does not use this term.

the trees lie in the borderland between trees and shrubs and it is immaterial into which class they are placed.

Regarding the growth-forms 28 species are erect and 12 prostrate or semi-prostrate. Of the erect shrubs 17 are tall (3 m or more), 9 of medium size (1—3 m) and 2 small (less than 1 m); their growth-forms and the number of species to each are! — bushy-shrubs 18; tree-composites 5; divaricating-form 2; flat-stemmed leafless 1; *Dracophyllum*-form 1; liane-like 1. The divaricating shrubs are more or less globose or cushion-like. The prostrate shrubs are either rock (10 species) or dune (2 species) plants; their growth-forms and the number of species to each are: — mat-like 8 (spreading 5, trailing 3); divaricating 2; open-cushions 2; the divaricating are of dense habit and may also be classed as "open-cushion".

The stems of most of the shrubs are slender, those of the shrub-composites and *Hymenanthera crassifolia* being the stoutest. This rock-xerophyte has gnarled, stout stems which, apparently rigid, are really quite flexible and hug the under-lying rock as tightly as possible forming stiff mats or low cushions some 30 cm deep and 1 m or so in diam. The more or less prostrate shrubs have generally flexible stems, those of *Pimelea arenaria* (dune-plant) and *Coprosma Kirkii* (rock-plant) being especially so. The wiry, reddish stems of *C. acerosa* have been already noted. *Muehlenbeckia Astoni* has stiff wiry, divaricating branches which by interlacing, build on stony shores irregular, rounded cushions 1.5 m high.

The roots of many species, especially dune and rock plants, are extremely long. *Plagianthus divaricatus* of salt-swamp and salt-meadow sends out very long roots horizontally through the soft substratum after the manner of the mangrove.

Coming now to the leaves, — 2 species have large leaves (10—20 cm long), 7 have them of medium size (5—10 cm), 9 small (2.5—5 cm) and 20 very small (2.5 cm and less). *Dracophyllum Sinclairii* with its grass-like leaves 4—12 cm long and *Carmichaelia Williamsii* leafy only when juvenile and with flat, rather thin, green stems about 8 cm broad, are not included in the above estimate. Regarding texture, *Senecio perdicioides* alone has thin leaves, those of the remainder being more or less coriaceous and in some species thick or fleshy. As to hairiness, 10 species *(Compositae)* have leaves tomentose on the under-surface; *Pimelea arenaria* (dune shrub) has sub-tomentose leaves and those of *Veronica pubescens* are covered with soft hairs on the under-surface.

Apart from the protection afforded to buds through the folding of their leaves or the position on the stem, some of the coastal shrubs exhibit special bud-protection. Thus in *Pittosporum* there are deciduous scales; in the shrub-composites a close covering of hairs; in *Cassinia* a sticky exudation; in *Coprosma* the bud is enclosed by glandular stipules and in *Veronica* the leaves of the bud remain pressed closely while it continues to increase in size before opening.[1])

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1) These remarks apply to these genera not merely for the coast but throughout the region.

c. Lianes.

The coastal lianes, 6 in number (scramblers 4, winder 1, tendril-climber 1), are of little moment, only *Ipomaea palmata* and *Sicyos australis* are high-climbing plants, the remainder at best straggle for a metre or so amongst shrubs, grasses or sedges while *Tetragonia trigyna* and *Fuchsia procumbens* are often prostrate merely. The stems of the last-named are woody, those of the remainder though perennial are herbaceous (1 semi-woody), that of *Sicyos* being fleshy, juicy and 6 mm diam.

Excepting *Fuchsia* which is more or less deciduous, the leaves are evergreen, broad and flat. All are thin except those of *Tetragonia* (fleshy) but those of *Angelica geniculata* and *A. rosaefolia* are waxy beneath. The leaves of *Sicyos* and the last-named are large; those of the remainder are rather small.

Certain forest-lianes as coastal plants may assume non-lianoid habits. Thus *Muehlenbeckia complexa* frequently forms a close elastic shrub-like mass of cushion-form. *Freycinetia Banksii* in the Western and Fiord districts creeps over rocky ground near the shore forming impenetrable thickets.

d. Herbs and semi-woody Plants including Water-plants.

It may be here explained that the distinction between herbs and semi-woody plants breaks down in a vegetation like that of New Zealand where nearly all the species are perennial and evergreen, and that, in not a few cases, it is a matter of opinion into which category some species should be placed. The term "semi-woody", as used in this book, indicates that a plant may have a considerable percentage of hard wood throughout its stems, or that these may be woody at the base only; it is obviously then a most elastic though convenient term.

The total number of herbs and semi-woody plants is 109 of which 9 are annuals or biennials, 100 perennials, 4 summergreen, 96 evergreen, 21 semi-woody, 88 herbaceous, 41 wandering, 68 spot-bound and about 46 xerophytes or subxerophytes. Regarding their height, — 2 species are very tall (more than 90 cm), 10 tall (60—90 cm), 19 of medium height (30—60 cm), 23 small (15—30 cm), 35 very small (less than 15 cm) and 20 hug the ground closely or are not more than 3—4 cm high.

The growth-forms together with the number of species in each are as follows: (1) Annuals &c. 9 consisting of, — prostrate 4, moss-like 3, tall erect 1, turf-making grass 1. 2) Semi-woody plants 21 consisting of, — a) Spot-bound 15 made up of, — tuft-ferns 2; tussocks 2 (rush); erect-branching 6; straggling 5; b) Wandering 6 made up of, — mat-form 4; erect-branching 1; sand-binding grass 1. 3) Herbaceous plants 79 consisting of, — a) Spot-bound made up of, — tufted-form 11 (ferns 3, grasses 7, herb 1); tussock-form 8 (grass 7, rush 1); straggling-herbs 6; erect-branching herbs 5; rosette-herbs 11; Iris-form 1; grass-mat 1; cushion 1; b) Wandering 35 made up of, — mat-form 16 (fern filmy 1, grass 1, herbs 14); erect-creeping 7 (fern 1, rush 2, grass 1, herbs 3); turf-making 7 (grass 2, rush 1, rosette-herb 1, creeping-herbs 3); sand-binders 2 (grass) and rosette-herbs 3.

Coming now to the leaves 7 species have very large leaves (over 20 cm long[1]), 8 large (10—20 cm); 15 of medium size (5—10 cm); 36 small (2.5—5 cm); 39 very small (2.5 cm and less); 74 succulent, thick or coriaceous; 31 thin; 94 glabrous and 11 hairy (tomentose 2).

A few species demand brief mention. *Plantago Hamiltonii* possesses small, rather broad, thickish, coriaceous, shining green leaves which overlap forming evenly shaped flat rosettes which grow so close together as to form a hard turf. *Gunnera arenaria* another rosette-plant makes large circular flat mats. *Eryngium vesiculosum* of salt-meadow has small rosettes of stiff, prickly, grey lanceolate leaves 10 cm long and by means of stolons it rapidly forms extensive colonies. *Stilbocarpa Lyallii*, of coastal scrub in Stewart Island, travels by means of stout hollow stolons 60—75 cm long which arch above the ground. At a certain stage in the growth of a stolon, a young plant is developed at its extremity which will possess 2—3 leaves before the young rhizome bent to the ground by the arching of the stolon will have rooted. Extensive colonies many square metres in area of this striking plant with its great bright-green, long-stalked, orbicular-reniform leaves, are formed in this manner, the stolons passing, in some instances, beneath rocks (see plate II), so that plants widely apart may be actually in connection.

There are 6 submerged water-plants, 4 of which have much branched thin filiform stems and leaves, and 2 have grass-like leaves and far-creeping, rooting rhizomes.

There is little of special moment to say concerning the stems of the coastal herbs. In general they are slender. Three of the ferns at times build short trunks with a maximum of some 15 cm in height, but this is in the moist climate of the S. The rhizomes of the sand-binding *Scirpus* and *Spinifex* attain an amazing length. *Urtica australis* growing amongst shingle has a thick, woody prostrate stem. *Euphorbia glauca*, a dune-herb, has unbranched aerial stems more than 1 m high, stout, terete and marked on the lower two-thirds with old leaf-scars.

The roots, in many cases bear a distinct relation to the habitat. Those of rock, dune and shingle are frequently of great length, but those of salt-swamp or salt-meadow are usually of medium length. The roots of dune species are often copiously provided with hairs to which the sand clings forming an investing layer. *Leptocarpus simplex*, as a plant of certain dunes of North Auckland, forms a stout trunk out of its roots and rhizome after the manner of *Carex secta*, but not nearly so high. In the S. this habit seems wanting.

1) These dimensions, used throughout this book, refer only to broad leaves, but narrow leaves are also included and are considered large, small &c. according to an estimate of their transpiring surface

2. Pollination.

Apart from the pioneer work of G. M. THOMSON (1881 a and b) and a few observations by CHEESEMAN, PETRIE and others, there is little to be learnt from botanical literature regarding the pollination of New Zealand plants, nor have I paid attention to the subject; a virgin field thus awaits cultivation so far as modern methods of investigation are concerned. Here and elsewhere all that can be supplied are a few statistics and general remarks. THOMSON showed that the prevailing belief, as voiced by WALLACE[1]) as to insects being strikingly deficient in New Zealand was not correct and that, though butterflies are few, there are many species of moths represented by numerous individuals while, even at that time the number of known species of beetles was more than 1300. Above all, THOMSON clearly showed what an important part is played by Diptera. Since 1881 many more species of insects capable of pollinating have been discovered so that there is no longer any question as to there being ample for the duty. That some of the species of butterflies have abundance of individuals may be seen by a visit to the montane tussock-steppe on any sunny summer's day. As for pollination by flies, not only are these insects attracted by special unpleasant odours but the cloying scents of certain species (*Cordyline australis*, spp. of *Clematis* &c.) bring them in great numbers.

Coming now to the actual coastal plants and leaving out of consideration the wind-pollinated *Gramineae* and *Cyperaceae*, the remaining species number 145 of which the flowers of 53 p. c. may be considered monoclinous and those of 47 p. c. more or less diclinous (dioecious 13 spp., monoecious 4, polygamous but in some cases dioec. or monoec. 51). About 60 p. c. of the species have flowers conspicuous enough to attract insects, while those of about 40 p. c. are small and dull-coloured though some are produced in great abundance. The attractive flowers are of the following colours: white 48 (55 p. c.); yellow 17 (20 p. c); purple 9; rose 3; lilac, pink, red and crimson 2 each; orange and blue[2]) 1 each. *Metrosideros tomentosa* and *Veronica speciosa* bear a profusion of brilliantly coloured blossoms that would be noticeable in any vegetation. My estimate of honey-flowers is 42 p. c. and of sweet-scented 25 p. c. both estimates being close to those of THOMSON based on his careful examination of 433 species in lowland Otago. The flowers of *Astelia Banksii*, *Plagianthus divaricatus* and *Veronica elliptica* are specially fragrant. No statistics can be given regarding dichogamy, homogamy or methods of pollination but a few special details are presented. Bird-pollination possibly occurs in *Metrosideros tomentosa*. The species of *Pimelea* are, as a rule, polygamo-dioecious, but the plants behave as if truly dioecious. *Fuchsia procumbens* has hetero-tristylic flowers as in the other New Zealand species; the stamens of the 3 forms do not vary in length. In *Selliera radicans* (CHEESEMAN 1877; 542—545) auto-

1) Geograph. distrib. of Animals 1: 457—464 and Darwinism, Ed. 2: 321. 1889.

2) The flowers of *Veronica elliptica* are at first of this colour but soon fade to white.

gamy is impossible and there is perfect correlation between shedding of pollen, trapping of this in the indusium peculiar to the *Goodeniaceae* and eventual protrusion of the stigma and its pollination by a fly.

3. Seasonal changes.

Speaking of New Zealand generally the distinction between the seasons is far less marked than in the N. temperate zone. Deciduous trees &c. are not only very few in number but they play, as a rule, little part in the vegetation, and summergreen herbs too are of trifling account. Thus the changes that strike the eye depend chiefly upon blossoming and fruit-ripening. But since so large a proportion of the species produce inconspicuous flowers and fruits, the effect is generally slight and the winter-aspect of forest, heath, steppe and dune is not strikingly different from that of midsummer. Here as in the other chapters devoted to biology, the matter of flowering receives special prominence, but the treatment is of the briefest. Further, it must be remembered, that the differences in time of blooming are quite considerable in passing from N. to S., or in certain parts from E. to W. so that much latitude must be given to general statements.

From about the end of May to the beginning of August the maximum period of rest is reached by the coastal plants, and in many of the species no growth of any moment is taking place. But even in the middle of June certain plants of a coastal forest may be in bloom in the Northern and Central provinces e. g., *Drimys axillaris*, *Dysoxylum spectabile*, *Coprosma grandifolia* and *Leptospermum scoparium*. The vegetation of salt-swamps and salt-meadows, where frosts are frequent, will be more or less browned, while the aerial parts of *Atropis stricta*, *Scirpus americanus* and *S. robustus* will be dead and those of *Salicornia australis* partially so. The rounded bushes of *Plagianthus divaricatus* will have assumed a blacker hue, for then they are either bare of leaves or a few linger in sheltered parts of the shrub. By the end of July, even so far S. as Banks Peninsula, *Mesembryanthemum australe* and *Linum monogynum* will be coming into bloom on sheltered cliffs. A little later *Hymenanthera crassifolia*, *Corynocarpus laevigata* and *Plagianthus divaricatus* in the N. commence to open their flowers, so that the latter fills the air of the salt-meadow with its honey-like fragrance. In the N., too, during September *Pittosporum crassifolium*, *P. umbellatum*, *Pimelea virgata*, *Coprosma Baueri* and *C. Kirkii* blossom freely. By the beginning of October flowering commences in earnest and the following coastal species bloom that month: *Scirpus frondosus*, *Carex pumila*, *Ranunculus acaulis*, *Pittosporum Huttonianum*, *Entelea arborescens*, *Angelica rosaefolia*, *Calystegia soldanella*, *Myoporum laetum* and *Senecio lautus*. November sees many additions to the flowers, and in the S. species which hitherto have bloomed only in the N. and C. now flower abundantly, but it is not until December that the salt-meadow of the Eastern district is lit up by sheets of canary-yellow *Cotula coronopifolia* and white *Samolus repens* var. *procumbens*. *Mimulus repens* growing in shallow water produces in profusion its showy lilac and yellow blossoms, but they are partly hidden by the foliage. *Atropis stricta*, *Calamagrostis Forsteri* var. *littoralis* and *Scirpus maritimus* will also be in bloom. On coastal rocks of Queen Charlotte Sound *Arthropodium cirrhatum* will be a striking feature; in the N. it will have been in flower since November. In the South Otago, Fiord and Stewart districts, banks not far from the sea will be draped by *Gnaphalium trinerve* with its conspicuous bracteate flower-heads. The floral feature of the coast however for the end of this month are the masses of dark-crimson produced by *Metrosideros tomentosa* in the North and South Auckland and the N. of the Egmont-Wanganui districts. Almost as striking is the flowering of *Olearia insignis* in December and January on coastal cliffs of the North-eastern district and of *O. angustifolia* in Stewart Island; in the Fiord district the closely related *O. operina* will flower. By the beginning of January, in the North Auckland district the embryos of *Avicennia* are falling from the trees, and a little later are anchored in the mud. During January and February the various coastal species of *Veronica* will be in bloom and the southern coastal moors be gay with the snowy blossoms of *Gentiana saxosa*. Many of the plants already mentioned continue to flower, and from this time onwards fruits ripen and seeds are shed. Several coastal species are late flowerers and it is not until April that *Olearia angulata*, *O. albida* and *O. Forsteri* are in full bloom, but generalliy speaking, except for such species as flower nearly all the year round (*Macropiper excelsum*, *Pisonia Brunoniana*) few species blossom after March, though blooms may be produced at abnormal times.

4. Epharmonic Variation.

Many coastal plants are extremely plastic, assuming quite different growth-forms according to marked environmental change. The transition from tree-form to shrub-form in a large percentage of the species has been already mentioned and certain cases cited. The juvenile *Coprosma Baueri* even when grown in good soil and a sheltered situation, is prostrate for a considerable period, i. e. there appears in the ontogeny of this species a certain habit of growth that in the adult can only be maintained under a special environment. *Dodonaea viscosa* growing in shelter is a tree 9 m high, but on certain shingly beaches it is altogether prostrate. *Plagianthus divaricatus* cultivated in rich, non-saline soil changes from a divaricating-form to a twiggy bushy-shrub. The far-creeping *Rumex neglectus* of stony beaches becomes almost a turf-maker on sour, wet coastal-moor soil. The rush-like leaves of *Crantzia lineata* in a dune-hollow are 2—3 cm long but in warmish shallow water they attain to more than 30 cm. The low-growing rather succulent herb *Crassula moschata* has green shoots in the shade but in bright light they are red. So too does the redness of the rush-like stems of *Leptocarpus simplex* increase with strong and decrease with weak illumination. *Calystegia Soldanella* when growing amongst tall herbage becomes a winding liane; similarly *Salicornia australis*, usually some 12 cm high when growing amongst *Plagianthus divaricatus* may become almost a scrambling liane with shoots attaining more than 1 m in length.

Speaking of coastal epharmony generally, there is certainly a strong relation between the form of the species that are exposed to the true maritime environment and the master-factors of the latter. This is well seen in the succulence of certain herbs &c. of a salt substratum, in the remarkable adaptations of the mangrove and in the sand-binding form of certain dune-plants belonging to different families or genera. At the same time there are many true coastal species whose form and structure afford no evidence of proximity to the sea, but these are rather plants of sheltered localities where coastal conditions are absent or much modified, and their presence is to be attributed rather to the mildness of the maritime climate than to any coastal adaptations.

Chapter IV. The Plant Formations.

1. Salt-water Associations.

a. The Sea-weed communities[1]).

About 450 species of marine *Algae* have been recorded for New Zealand of which probably one half are endemic, while a considerable number are of wide distribution. The actual range of the different species along the coast is still very imperfectly known, while accurate details as to their bathymetrical range are altogether wanting. It is clear however that sea-temperatures, in large part, govern their distribution in latitude, but no data are available as to local coastal and seasonal temperatures. All that can be said is that many species appear to be confined to the colder waters of the Fiord, South Otago and Stewart districts, while a few do not occur outside the Northern botanical province. Further, the study of the New Zealand Algae has hitherto been entirely floristic, so that quite general statements as to their synecology must be made.

The usual colour-range is shown on the New Zealand coast. Near high-water mark, there are a few species of green sea-weeds, usually in no great quantity, consisting chiefly of cosmopolitan forms of *Ulva* and cosmopolitan and local forms of *Enteromorpha* with abundance of the narrow ribbons of *Scytosiphon lomentarius* 30 cm, or more, long. Where there are moderately shallow rock-pools near low-water mark, brown algae predominate, though here too a few *Chlorophyceae* occur, e. g. *Bryopsis vestita* forming, with its dark, olive-green pinnae little crowded tufts 4—8 cm high, and the thick, fleshy, dark-green *Codium adhaerens* clinging in masses to the under-

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1) This is based altogether on information most generously supplied by Mr. R. M. LAING.

sides of stones. In deeper pools species of *Chaetomorpha* and *Caulerpa* occur; the long, translucent, green, bead-like strings of *Ch. Darwinii* and the bunched berry-like beads of *Ch. sedoides* being both abundant and striking. Amongst the brown sea-weeds the large beads of *Hormosira Banksii*, various forms of *Cystophora* and *Carpophyllum maschalocarpum* are of physiognomic importance in any rock-pool. In the deeper pools, *C. phyllanthum*, *Ecklonia Richardiana* and even clumps of *Lessonia variegata* appear. Here too occur a few of the hardier red sea-weeds, e. g.—*Ballia callitricha*, *Euptilota formosissima* and the commoner species of *Plocamium*. Frequently, the rocks of the shallower pools are covered by a layer of the commonest corallines.

On the inter-tidal rocks, there are different associations. Amongst the commoner species are,—*Adenocystis Lessonii*, its pyriform bladders some 5 cm long, solitary or clustered together; *Colpomenia sinuosa*, its spherical or hemispherical sacs a few centimetres in diam.; the annual *Splachnidium rugosum*, *Scytothamnus australis* and species of *Porphyra*. Nearer to low-water other species appear; in the stiller waters, *Carpophyllum phyllanthum* is abundant, *Desmarestia ligulata* is frequent together with *Zonaria Turneriana*, the endemic monotypic *Landsburgia quercifolia*, *Sargassum Sinclairii* and occasionally other species of that genus.

In more open waters, *Marginaria*[1] *Boryana* and *M. Urvilleana* are frequently to be seen. On rocks exposed to the full fury of the waves is an almost pure association of the immense *Durvillea utilis* (Plate III, Fig. 4) forming flat sheets and long, leathery thongs; with it may be the somewhat similar but much smaller *Xiphophora chondrophylla* and possibly *X. gladiata* also. Various red sea-weeds also occur, notably some of the polymorphic forms of the coarser *Gigartinae* e. g. *G. angulata*, *G. decipiens* and species of the allied *Pachymenia*, especially *P. lusoria*.

At from 30—90 cm below low-water, the more delicate red sea-weeds appear. In the calmer waters are species of *Callophyllis* (e. g. *C. Hombroniana*, *C. calliblepharoides*), *Chrysymenia apiculifera*, *Epymenia Wilsoni*, *Plocamium brachiocarpum*, *Melanthalia abscissa*, *Gracilaria confervoides*, *Cladhymenia oblongifolia* and occasional species of *Nitophyllum*, *Delesseria*, *Laurencia* and *Euzoniella*.

In the deeper and stiller waters are the more fragile red sea-weeds which belong, in large measure, to the following genera:—*Callithamnion*, *Griffithsia*, *Polysiphonia*, *Rhodomela*, *Rhodophyllis*, *Bostrychia*, *Delisea* and *Gelidium*, but our knowledge of this interesting association is most imperfect.

For kilometres at a time along a rock-bound coast but never where exposed to heavy seas, there is often a broad belt of *Macrocystis pyrifera*, the stems anchored below the surface, it may be to loose stones at a depth of 15—30 m, or even deeper, and the long, ribbon-like leaf-segments floating on the water, supported by their inflated bladders.

1) An endemic genus with strap-shaped lamina beset on one side only with spindle-shaped receptacles.

b. Zostera association.

There are two species of *Zostera* in New Zealand, *Z. nana* and *Z. tasmanica*[1]), the former making a pure association between tide-marks and the latter being permanently submerged.

Z. nana forms extensive grass-like colonies on the muddy floor of estuaries in all the botanical provinces. The association is uncovered only at spring tides, the grassy leaves lying on the mud, through which creeps the slender brittle rhizome.

2. Brackish-water submerged Associations.

Ruppia maritima forms submerged masses of filiform stems and leaves on the floor of lagoons &c. and slowly-flowing streams in somewhat brackish water.

Althenia bilocularis, a smaller plant of similar growth-form, also occurs in some localities on the east of the South Island under identical conditions.

Zannichellia palustris, another ecologically equivalent species, occupies similar stations to the above.

3. Salt Swamp.

a. Mangrove swamp (Tidal forest or scrub).

In New Zealand this formation possesses but one species, *Avicennia officinalis*, which forms belts or patches of scrub or low forest, as the case may be, between the tide-marks in shallow estuaries, tidal rivers, sheltered bays and the like. It is restricted to the Northern botanical province and is to be seen in its greatest luxuriance in the extensive estuaries and tidal rivers of the North Auckland botanical district. (Plate IV, Fig. 5).

The presence of the formation depends chiefly upon the following:— 1. A muddy substratum which, though generally deep, may be quite shallow and overlie rock. 2. Absence of frost. 3. Warmish water during summer. 4. Tide-erosion of insufficient power to uproot the young seedlings.

The substratum generally consists of an extremely soft and sticky mud which is light brown on the surface but, at a little depth black, shiny and of evil odour. In places, very shallow pools of water, left by the retreating tide, lie on the surface of the water-saturated ground, which is everywhere honeycombed by the holes of crabs, the orifices varying from 1.5 cm to considerably less, and out of which water flows as one steps on the mud.

When growing in the greatest luxuriance, the trees, 9 m or more high, form a close belt dull brownish-green in colour, bounding the shore of the

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1) There appears to be some doubt as to the species. HOOKER referred a specimen from Auckland harbour to *Z. marina L.*, remarking it was perhaps *Z. angustifolia* Roth. GRAEBNER (Pflanzenreich. *Potamogetonaceae*: 31), cites only *Z. capricorni* Aschers., as occurring in N. Z., and doubts the occurrence of *Z. tasmanica* (p. 32). CHEESEMAN (1906: 754) gives the names as above, but is not certain as to the exact position of the deep-water plant.

estuary or even occupying the centre of the river-bed, the outer limit being determined by the average low-water mark. At high tide, only the crowns of the trees are visible, the lower parts being under water, but, at low-water, the muddy floor is exposed and the spreading branches and bare trunks are visible. Everywhere the more or less limpet-covered, asparagus-like pneumatophores rise up in thousands, projecting from the mud for a height of some 20 cm on an average. Some are solitary, but others are more or less bunched together. Growing scattered amongst them are many young plants of *Avicennia* of all sizes, especially near the shoreward margin of the swamp. The innumerable erect pneumatophores not only play a biological part, but they strongly oppose tidal erosion and in many places, though very slowly, they promote the deposition of mud and other river-borne matter, until eventually the swamp may be replaced by salt-meadow.

b. Leptocarpus-Juncus swamp.

The substratum of *Juncus-Leptocarpus* swamp differs from that of Mangrove in that it is much firmer and less muddy. The soil may be clay, loam, sand or mixtures of these; shells of certain molluscs are abundant and the surface is riddled with the holes of crabs[1] *(Heterograpsus crenulatus)*. The water with which the ground is saturated is brackish, and though there is a maximum of salt that can be endured no minimum is demanded by the species, yet, if the water be too fresh, the halophytes come into competition with ordinary swamp-plants, e. g. *Typha*, *Phormium*, and cannot hold their own.

The association occurs on the floor of tidal-rivers and lagoons, on ground subject to be flooded only by the higher tides. Frequently, the river erodes one bank and deposits sediment near the other; on this when it reaches a certain height, and if the tidal-scour be not too great, various halophytes become established from seeds brought by birds or the water itself, or vegetative portions deposited by the tide. Later on, some of the soil-particles, continually brought by the water, are held between the plants themselves and their shoots, together with the products of decay, so that the surface is gradually raised and the swamp slowly transformed into salt-meadow. Earlier on, the Mangrove and *Zostera* formations, catching and holding the mud, may prepare the requisite conditions for *Juncus-Leptocarpus* swamp.

The first plant to appear is *Scirpus americanus*, which, even after the taller members are established, holds its own on the wetter ground, thanks partly to its power of increase by means of the far-spreading rhizomes. Eventually, the taller close-growing *Juncus* or *Leptocarpus* excludes the light and the *Scirpus* is doomed.

Throughout most of New Zealand, *L. simplex* and *J. maritimus* var. *australiensis* dominate, but the latter does not extend on the east of the South

1) These certainly provide surface-drainage, but they also help the substratum to be more quickly and thoroughly saturated with salt-water than would be the case were they absent.

Island beyond Timaru; the great salt-swamp near Invercargill, for example, consists of *Leptocarpus* (dominant) and some *S. americanus*.

The general physiognomy of the association depends upon the dominant rush-form. Seen from a distance, it presents a dark even surface, but usually the *Leptocarpus* is slightly taller than the *Juncus*, while the *Scirpus* forms greener patches. Perhaps 70—80 cm might be considered the usual depth of the vegetation. Growing on the dryest ground, and not exposed to salt-water, except at the highest tides, is a girdle of the dark-coloured rounded bushes of the divaricating-shrub, *Plagianthus divaricatus*, 90 cm high or less. Landwards of this comes salt-meadow.

Leptocarpus[1]) and *Juncus*[2]) form pure girdles or clumps, but which is the more salt-tolerating, I do not know, since in different localities, either may form the seaward girdle. Here and there in the main mass of the association are tussocks of *Carex litorosa*. *Cladium junceum* is common in the Northern botanical province. Where deep pools occur, there is abundance of *Scirpus robustus* and with it *S. americanus*. Near the junction of salt-swamp and salt-meadow, various species of the latter come in, especially, — *Salicornia australis*, *Apium filiforme*, *Selliera radicans* and *Cotula dioica*.

c. *Scirpus lacustris* association.

As the water of the shallow tidal river becomes less salt, a girdle of the tall rush-like *Scirpus lacustris*[3]), 1.5 m or so, in height, fringes the bank, but in the South Otago, Stewart and perhaps Fiord districts the association is absent. Although not depending in the least upon the *Scirpus*, *Plagianthus divaricatus* frequently forms a girdle on the landward side of the former, its dark hue contrasting with the green of the *Scirpus*.

d. *Mimulus repens* association.

Where sluggish streams flow through salt-meadow, but not in every locality, the above association occurs. Usually, there is a fairly deep, flowing portion of the stream and a shallow sluggish part, this latter caused by a slight overflow. In the shallower part, *M. repens*[4]) may be dense enough to hide the water. Through it may grow some *Scirpus americanus*, *Triglochin striata* var. *filifolia* and perhaps a little *Cotula coronopifolia*. In the deeper part there is *Scirpus robustus* with an undergrowth of more or less *Mimulus*. Greater stagnation of water soon brings in *Cotula coronopifolia* with floating stems, and the other plants are absent.

1) This is not in the least dependant upon Na Cl since it grows plentifully on the shores of Lakes Te Anau and Manipouri.

2) Occurs inland on the Volcanic Plateau but in the vicinity of hot-springs.

3) The species also occurs on margins of lakes &c., at some considerable distance from the sea, ascending to 450 m, according to CHEESEMAN (1906: 778).

4) A prostrate perennial herb with stout, succulent, creeping, rooting stems; prostrate or sub erect branches and small, obtuse, entire succulent leaves, 4 mm long.

4. Salt-meadow.

This association occurs on ground subject to flooding by brackish water brought at times of exceptionally high tides, or on wind-swept slopes &c. liable to occasional drenching by sea-spray. In winter, or after heavy rain, pools lie everywhere on the flat meadows. The soil may vary from clay to sand. None of the species are dependant upon excess of Na Cl in the substratum, though such is generally present.

The composition of the association is fairly uniform throughout New Zealand, but there is no rule as to dominance of any particular species. About 21 species are common in some part or other of the formation belonging to 13 families and 17 genera and containing 1 shrub, 15 herbs, 3 rush-like and 2 grass-like plants.

Juncus maritimus var. *australiensis*, *Leptocarpus simplex* or *Plagianthus divaricatus* may be abundant in places, and probably, prior to the settler's fires, were more plentiful still, but the physiognomy of the meadow depends less on the rush-form than on the presence of a close and even turf made up of the far-creeping perennial herbs *Selliera radicans*, *Samolus repens* and *Cotula dioica*. Equally abundant, indeed at times dominant, is the succulent *Salicornia australis*, and the summer-green grass *Atropis stricta* is also very common. Other important species are:—*Triglochin striata* var. *filifolia*, *Atriplex patula*, *Suaeda maritima*, *Spergularia media*, *Apium prostratum*, *A. filiforme* and *Cotula coronopifolia*. In the S. of South Otago district and in Stewart Island, *Cotula Traillii* and *C. pulchella* are plentiful, but there the association is related to coastal-moor described below.

5. Coastal-moor.

This remarkable association occurs locally in the S. of the South Otago and Stewart districts and possibly in the Fiord district. The most typical moor is on the W. of the Bluff Peninsula to the S. of Ocean Beach, but smaller examples occur, at various localities, on the shore of Foveaux Strait and on some of the small islands in the Strait itself. The presence of the association depends upon a substratum of sour peaty soil, the result of the subantarctic character of the climate and the nature of the plant-covering[1]). The habitat is also exposed to showers of sea-spray, so that there will be a greater percentage of NaCl in the soil than in the case of lowland-moor. Water frequently lies in pools and some of these are permanent.

The species number about 35 belonging to 18 families and 30 genera and consisting of 22 herbs, 10 grass-like plants, 1 rush-like and 2 ferns. Several typical salt-meadow plants are common, e. g.—*Salicornia australis*, *Samolus repens* var. *procumbens*, *Selliera radicans*, and *Cotula dioica*. But it is the presence of forms of an alpine or subantarctic character that specially

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1) That is to say, certain species occupy the ground, thanks to the favouring climate, these form peat and species more peat-tolerating still, enter in, and intensify the oxylophytic conditions.

characterize the formation, e. g. — *Blechnum durum*, *Scirpus aucklandicus*, *Agrostis muscosa*, *Rumex neglectus*, *Montia fontana*, *Gentiana saxosa*, *Myosotis pygmaea* var. *Traillii*, *Euphrasia repens* and *Plantago Hamiltonii*.

The plant-covering consists of an even turf of extreme density[1]) owing to the plants having their rosettes or leaves pressed close to the ground. Its composition is not uniform throughout, but more or less distinct sub-associations may be recognized, defined by the dominance of *S. radicans*, *C. dioica* or *P. Hamiltonii* respectively, though the combinations merge one into another. The round, green cushions of *Euphrasia repens* are everywhere, each about 12 cm in diam. which, when thickly covered with their small, snowy flowers are most striking. *Gentiana saxosa*, too, in full bloom, is equally conspicuous. The physiognomy of the turf itself depends upon which species is dominant. The dense shining rosettes of *P. Hamiltonii*, all touching, the leaves glossy-green but blackish-brown at the base, covering the ground to the exclusion of all else, are a remarkable sight. Colonies of *Rumex neglectus* make green patches; dominance of *C. dioica* lends a reddish-brown colour to the turf; the tiny starry flowers of *Asperula perpusilla* betray its presence, otherwise hardly noticeable. Increasing wetness of the ground brings in abundance of *Montia fontana*, and *Crassula moschata* occurs in profusion, fringing pools. *Blechnum durum* and *Asplenium obtusatum*, their fronds flattened to the soil, are everywhere common; tussocks of *Scirpus nodosus* are occasionally plentiful, or those of *Carex appressa* may make a pure growth, and, in some places, the still taller Fuegian *C. trifida* will occur.

On the low flat sandy ground to the W. of the New River Estuary, the association is allied to coastal-moor, on the one hand, and dune-hollow, on the other; *E. repens*, *P. Hamiltonii*, *Claytonia australasica* and *Nertera Balfouriana*, for example, represent the moor, and *Gunnera arenaria*, *Geranium sessiliflorum*, *Selliera radicans*, *Acaena novae-zelandiae*, *A. Buchanani* var. *longe-filamentosa* and *Raoulia Beauverdii* the dune-hollow.

6. Strand.

a. Sandy Shore.

Wide wind-swept stretches of sandy beach are frequently destitute of plant-life, the lower shore being washed by the sea, while the upper loose sand above high water mark is the sport of the wind. Specially high tides too extend far beyond the average limit, and the undiluted sea-water is detrimental to the well-being of land-plants. Notwithstanding this, the dune-plants, *Spinifex hirsutus*, *Scirpus frondosus* and *Carex pumila* creep over the loose sand, or build hillocks.

Where conditions render sand-movement sufficiently feeble a few plants will be present, but, in any case, the number of species is small. *Ranunculus*

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1) So dense and smooth, indeed, that it lends itself to people carving their names &c. on its surface, especially where *Plantago* and *Selliera* are combined.

acaulis, its tiny leaf-rosettes half-buried, their blades flattened to the sand, often forms small colonies. *Calystegia soldanella* makes green patches, or isolated plants may be dotted about, as may the grasses *Festuca littoralis* and *Calamagrostis Billardieri* and the stiff-stemmed tussocks of *Scirpus nodosus*. *Salsola kali* is fairly common in some places. The pale-green, succulent *Atriplex Billardieri* occurs sparingly throughout, and forms mats upon the sand. It is abundant on certain beaches in Stewart Island, where it forms a girdle on the upper shore 2 m wide, the stems half-buried and the plants some 90 cm. apart. In the N. the grass *Zoysia pungens* is fairly common.

b. Stony shore.

Stony shores vary greatly in their physical characteristics, for there are many gradations from sandy-gravel to rocks worn flat, or where there is an uneven stony surface with large rocks standing out and affording shelter.

The florula of stony shores is much richer than that of sandy; the firmer substratum, the moisture beneath the stones, in the case of shingle or gravel, and the greater degree of shelter, all favour growth-forms and meet physiological requirements to which sandy shores are hostile. With but few exceptions, the species belong to other formations, salt-meadow, rock, heath, forest and river-bed all contributing. Besides the actual strand, gravel terraces adjacent are here dealt with.

1. Beach of loose stones.

Beaches of this class offer different conditions according to size of stones, state of consolidation and amount of sand present. Between sand and gravel there is merely a question of degree, so that coarse sand and fine gravel beaches have much the same plant-covering. Where the stones are large enough to be called shingle, the conditions approximate to those of lowland river-bed, excepting that the latter has usually a greater water-supply and more available soil between the stones, while the spray-factor is absent. But, as will be seen, certain river-bed species do occur on some shores though generally well away from the sea.

Only the following three species can be considered as specially belonging to stony shore, but all at times occur in other formations, — *Rumex neglectus*, *Urtica australis*, *Lepidium tenuicaule*. Other species, several not specially coastal, but common on many shingly and gravelly shores are, — *Scirpus nodosus*, *Mariscus ustulatus*, *Carex pumila*, *Phormium tenax*, *Muehlenbeckia complexa*, *Tetragonia expansa*, *Linum monogynum*, *Pimelea prostrata*, *Apium prostratum*, *Calystegia soldanella*, *Cassinia leptophylla* and *Senecio lautus*.

Where the boulders are largest, vegetation is the most scanty, the commonest plants being the halophytes, *Apium prostratum*, *Calystegia soldanella* and *Senecio lautus*, this latter through its strong plasticity being able to respond rapidly to change of conditions. Further from the influence of the waves, there may be *Phormium tenax*, *Scirpus nodosus*, and excepting south of about latitude 43°, *Mariscus ustulatus* and *Lobelia anceps*.

The terrace bounding the shingle shore, being both more stable and less halophytic, possesses a more varied plant-covering. *P. tenax*, either in clumps, or as a continuous belt is a fairly common feature. On Cuvier Island it is mixed with *Arundo*; in South Canterbury it forms for a considerable distance a more or less continuous girdle; at Big Bay and Paringa (South Westland), this belt is so near the sea that, in rough weather, it arrests the floating drift-wood. *Muehlenbeckia complexa*, as a mat-plant, is a common feature of terraces or high foreshores, and such mats favour the settlement of other plants e. g. *Rhagodia nutans*, *Linum monogynum*, *Senecio lautus*, and at the present time certain introduced species. The following are some of the more common species of shingle or boulder terrace: — *Pteridium esculentum*, *Scirpus nodosus*, *Carex testacea*, *Acaena novae-zelandiae*, *Oxalis corniculata*, *Linum monogynum*, *Euphorbia glauca*, *Pimelea prostrata*, *Leptospermum scoparium*, *Apium prostratum*, *Dichondra repens*, *Cassinia leptophylla* or *retorta* according to latitude. The prostrate form of the wind-tolerating tree *Myoporum laetum* occurs on boulder banks at Moko Hinou and Cuvier Islands, North Auckland district.

The following shingle beaches require special mention: — 1. The Nineteen Mile Beach, N. of the R. Rakaia (Eastern district). This consists of loose shingle, small stones and sand. Above high-water mark the surface is flat, thence it sinks to the base of a terrace making a hollow into which debris is carried by extra high tides. The shingle is thin, flat and averages perhaps 13×10 cm. Plant-colonization begins here, the first comer, favoured by the sand, being *Calystegia soldanella*, and the next, *Apium prostratum* which grows, at times, amongst the drift-wood. Other species are: — *Carex pumila*, *Polygonum aviculare* (introduced), *Chenopodium glaucum* var. *ambiguum* and *Senecio lautus*. The face of the terrace is steep and composed of loose shingle mixed with a good deal of sand. At a short distance beneath the surface, it is quite moist. Its plant-covering is open and consists of most of the species occurring on the summit of the terrace. This, some 40 m broad, has a downward slope landwards until the surface becomes so much depressed as to be swampy. A grass-girdle 20 m wide, consisting largely of introduced species, extends from the swamp to the open vegetation of the upper terrace. Here the principal plants are: — *Raoulia lutescens*, a mat or low cushion-plant of dense habit, and two leafless shrubs which form round mats of terete (*Muehlenbeckia ephedroides*), or flat, (*Carmichaelia prona*) stems. These three are normally species of river-bed or stony steppe and are subalpine as well as lowland. The aerial shoots of the *Muehlenbeckia* are annual and their decay makes a soil in which certain plants become established, e. g. — low tussocks of *Poa caespitosa*, small cushions 4—5 cm in diam. of *Colobanthus Muelleri*, *Senecio lautus* and *Apium* together with the introduced *Holcus lanatus*, *Silene anglica*, *Sonchus arvensis* and *Anagallis arvensis*; in this manner, the girdle of grassland has been formed. More abundant than the grey circular mats of *Muehlenbeckia* are the low silvery cushions of the *Raoulia* which, for the most part, present a broken face on the windward side through damage by the sand-laden wind. This plant is also a soil-maker. *Pimelea prostrata*, orange cushions of *Scleranthus*, patches of *Ranunculus acaulis* and *R. rivularis?* and lines of tussocks of *Poa caespitosa* are common.

2. At several places on the shingly shore of Cook Strait near Wellington *Raoulia australis* and the steppe xerophytic herb, *Aciphylla squarrosa* are companion plants. Here also the usually erect shrubs *Plagianthus divaricatus* and *Coprosma propinqua* form stiff mats.

3. North of Greymouth, on the shingle beach, *Muehlenbeckia axillaris* clothes the grey stones with its round mats of slender stems and small green leaves, and is found even amongst the drift-wood. *Wahlenbergia congesta*, *Phormium tenax*, *Scirpus nodosus*, flat wiry mats of *Coprosma acerosa*, *Scleranthus biflorus*, *Calystegia soldanella*, *Scirpus frondosus* (where sand has blown), *Carex testacea*, *Euphorbia glauca* and much-dwarfed bushes of *Dodonaea viscosa* are all more or less abundant.

4. On the pebbly beach south of Awarua Harbour, South Otago district, on the gravel terrace beyond reach of the waves, mats of *Muehlenbeckia complexa* assist in furthering plant-colonization, not by supplying soil, but by catching seeds and sheltering the seedlings. On them grow tussocks of *Poa caespitosa*, while mats of *Acaena novae-zelandiae* and *Pimelea prostrata* are common.

5. Beaches of fine gravel on Dog, Centre and Ruapuke Islands (Stewart district), and Preservation Inlet (Sounds district) &c. possess the following characteristic species: — *Rumex neglectus*[1]), *Ranunculus acaulis*, *Lepidium tenuicaule*[2]) and *Myosotis pygmaea* var. *Traillii* together with *Scirpus aucklandicus*, *Carex pumila*, *Chenopodium glaucum*, *Atriplex Billardieri*, *Crassula moschata*, *Tetragonia expansa*, *Geranium sessiliflorum* and *Cotula pulchella*. All the above are not usually present on any one beach.

6. On the shingle-beach of Dog and Centre Island *Urtica australis* is abundant. It has a stout woody stem, partly prostrate and buried by the stones, but still 21 cm high. The thin, cordate leaves, 9.5 cm long form semi-rosettes at the ends of the branches.

2. Rocky shore.

The surface is generally more or less uneven, so that water, soil and fragments of rock collect in the depressions. The shallow soil-deposits are readily soaked with sea-spray, and conditions are thus provided for halophytes. In consequence, salt-meadow species, forming either miniature salt-meadow, or dotted about, are characteristic of rocky shores. Most common of all is *Salicornia australis*, which may exhibit great luxuriance. But the two species

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1) Low evergreen herb with stout, far-creeping subterranean stem and thickish, green, linear-oblong leaves flattened to the ground in full light, but erect in shade.

2) Small evergreen herb with extremely long, deeply-descending root and small rosette of leaves flattened to the ground.

of *Apium*, *Crantzia linearis*, *Samolus repens* var. *procumbens*, *Selliera*, *Suaeda maritima*, *Leptocarpus* and *Scirpus nodosus* may be all common. In the southern botanical province, *Scirpus aucklandicus* and *Crassula moschata* are frequent, this latter extending to the northern shore of Cook Strait. Where the rock-floor is dry, and at some distance from the sea in the Central botanical province, *Cassinia leptophylla* and low bushes of *Muehlenbeckia complexa* are common. *Mariscus ustulatus* is abundant where water lies.

7. Dune.

a. General.

Not less than 127000 hectares of the coast-lands consist of dunes, which, in some places, extend inland for a distance of 12 km. The most extensive areas are on the W. coast of the North Island, but considerable dunes also occur on the E. and N. In the South Island and Stewart Island, the area, 9700 hectares, is still considerable.

The plant-covering of the dunes is fairly uniform throughout New Zealand, the Lord Auckland and Kermadec Islands excepted, but certain latitudinal changes are evident due partly to climatic and partly to historical causes. *Scirpus frondosus*, *Calamagrostis Billardieri*, *Festuca littoralis*, *Euphorbia glauca* and *Coprosma acerosa* occur on all unstable dunes. On the other hand, *Spinifex hirsutus* hardly extends beyond the Central botanical province. The three ecologically equivalent species of *Cassinia* (*retorta*, *leptophylla* and *fulvida*) are each, in the order named, the dominant, or sole form, in the Northern, Central and Southern botanical provinces. *Pimelea arenaria*, common on dunes in both the main islands, is represented in the South Otago district and Stewart Island by a form of *P. Lyallii*. *Geranium sessiliflorum* is abundant on semi-stable dunes in the South Otago district and Stewart Island, but absent elsewhere. Certain species of *Raoulia* are confined to particular localities and conditions.

The dune-areas are no longer in their primitive condition, nevertheless, in many places, the associations are virtually unchanged. For many years utilised as grazing ground, the customary burning has taken place, and, in consequence, the area of moving sand has greatly increased, so that various non-coastal formations have been invaded and converted into dune.

A typical, highly-developed dune-area in New Zealand consists of a fairly even-topped low wall of sand the *foredune* which rises from the upper strand beyond reach of an ordinary tide (Plate V Fig. 6). Behind this lies an irregular collection of more or less unstable sandhills and hollows, the *dune-complex*, behind which, again, will be level tracts of considerable extent from which the hills have migrated altogether. This latter area is bounded on the landward side by high bare sand-masses, the wandering-dunes, quite devoid of vegetation, each hill with a long, gentle windward-slope but a steep leeward-descent. Sometimes, the wandering-dune is absent and is replaced by old stable hills covered with a thin layer of blackish soil, bearing a close covering of grass or heath. Swamps and shallow sheets of water are common features in extensive dune areas.

The dune-landscape does not everywhere present the features described above. Generally, there is no regularly shaped foredune. The wandering dune may not be confined to the landward boundary, but the hills of the dune-complex, advancing one upon another, will have formed, or be still forming wandering-dune. Hollows may be either slowly extending as a hill recedes, or in process of extinction as hills advance, or a stream of sand pours through some opening.

A dune-area may be restricted to a few hillocks or a slight ridge on the upper shore. On the other hand, there may be a series of miniature mountains more than 60 m high with deep valleys between. In some parts of Taranaki and Auckland, cliffs, themselves often consolidated dunes, face the ocean, while at high-water there is no exposed beach at their base. Such are capped by enormous deposits of sand which are not infrequently advancing inland.

The ecological conditions governing dune-vegetation are extremely severe and for the most part are strongly xerophytic in character. But the special feature is the drifting-sand which can only be withstood by plants possessing special sand-binding "adaptations" in no small degree. On some parts of the coast, "salt-gales" rage at times, the effect of which is felt for many kilometres inland, but the dune-species are immune against these.

About 150 species are found on the dunes as a whole but only some 50 are common. The following are virtually confined to the dune-areas: — (Shrubs) *Pimelea arenaria*, *Coprosma acerosa*, *Cassinia retorta*; (Herbs) *Ranunculus recens*, *Euphorbia glauca*, *Gunnera arenaria*, *Calystegia soldanella*; (Grass-like plants) *Spinifex hirsutus*, *Calamagrostis Billardieri*, *Festuca littoralis*, *Bromus arenarius*, *Scirpus frondosus*, *Carex pumila*; (Rush-like plant) *Eleocharis neo-zealandica.*

The following are extremely common: — (Shrubs) *Leptospermum scoparium*, *Cassinia leptophylla*, *C. fulvida*; (Herbs) *Phormium tenax*, *Acaena novae-zealandiae*, *Oxalis corniculata*, *Epilobium Billardieranum*, *Crantzia lineata*, *Lobelia anceps*, *Selliera radicans*; (Grass-like plants) *Zoysia pungens*, *Arundo conspicua*, *Mariscus ustulatus*, *Carex testacea*; (Rush-like plant) *Leptocarpus simplex.*

Dune-vegetation exhibits a gradual procession of events in harmony with the increasing stability of the substratum, the foredune marking the unstable commencement and the fixed inland sand-hill the stable climax. Stages also occur where a new class of associations branches off that may be merely transitory or become permanent, its persistence depending upon the stability of the dune-area as a whole.

b. Sand-grass dune.

This, the first stage in dune-evolution is distinguished by its extreme instability which permits the presence only of the sand-binding *Scirpus frondosus* or

Spinifex hirsutus, one or both according to the botanical district. In the Northern and Central botanical provinces, where both plants are present, they rarely intermix, while their characteristic colours, — silvery (*Spinifex*), yellow (*Scirpus*), plainly indicate which dominates, giving the dune also a special physiognomy. *S. hirsutus* does not extend inland for any distance, but *S. frondosus* occurs, wherever there is drifting sand. In the S. of the South Otago district *Festuca littoralis* is an early comer, and it is sometimes a primary dune-builder. Occasionally, the tufts of *Spinifex* or *Scirpus* form a close covering, but usually there are more bare patches than vegetation. At certain places on the W. coast of the Ruahine-Cook district a very uniform foredune, looking like an artificial embankment, extends for several kilometres at a time covered with *Spinifex*.

Embryonic dunes frequently occur both on the foreshore and sand-plain. A plant of either of the sand-binders becomes established, functions as an obstacle, a tongue of sand is formed on its leeside into which the rapidly-growing rhizome extends, and with simultaneous increase of sand and growth of plant a small dune is formed.

As sand-grass dune becomes more stable, *Calystegia soldanella*, *Calamagrostis Billardieri*, *Festuca littoralis* and *Scirpus nodosus* will gain a footing and probably also some of the sand-tolerating shrubs. The rarer *Euphorbia glauca* belongs to the same association. In Stewart Island, *Sonchus littoralis* may be present. *Calystegia soldanella* often covers the sand completely with a shining green mantle. Low dunes of that kind persist for a considerable time, the dune itself acting as a solid obstacle thus causing a protecting wind-trough to be formed between itself and the advancing sand.

c. Shrub-dune (Plate V Fig. 7).

Semi-stable shrub-dune is the second stage of progressive dune-evolution. The shrubs present are only those adapted to drifting sand, e. g., *Coprosma acerosa*, one or more of the species of *Cassinia*, and *Pimelea arenaria*. Generally, *C. acerosa* or *Cassinia* is dominant, the former conspicuous through its curious growth-form and reddish colour, whereas the *Cassinia* is grey or yellow, according to the species. *Calystegia soldanella*, *Festuca littoralis*, *Calamagrostis Billardieri*, *Scirpus nodosus* and sometimes *Arundo conspicua* may be members of this association.

At a greater distance from the sea, or when exposed to weaker sand advance or erosive wind-action, the above shrubs will form a closed covering and may be reinforced by others, especially *Leptospermum scoparium*. The great tussocks of *Arundo conspicua*, and the *Iris*-like green masses of *Phormium tenax*, are frequently present, the latter being extremely common in the North Auckland district. There too, *Leptospermum ericoides* and *Styphelia fasciculata*, not erect but forming spreading mats, are very abundant.

d. Fixed-dune.

This, the climax of constructive dune-building, frequently lies far back from the sea, and is of considerable age and perhaps denotes a rising coast. In places where the wind strikes obliquely, or is not frequent, fixed-dune may lie just behind the foredune.

The sand is covered by a much more cohesive humus-containing layer of blackish sand, than is that of unstable dune. It is sometimes as much as 30 cm in depth, formed from the decay of many generations of plants.

At the present time, the vegetation is much modified. It consists of grassland or a heath of *Cassinia*, *Leptospermum* or *Pteridium esculentum*. No longer primitive, the grassland contains many introduced grasses and *Leguminosae*, together with forms of *Danthonia pilosa* and *D. semiannularis*. *Zoysia pungens* is common in northern localities, but it is generally found in less loamy stations. *Phormium tenax*, *Arundo conspicua*, *Microlaena stipoides*, *Discaria toumatou*, species of *Carmichaelia* and *Scirpus nodosus* are common members in many localities. On the northern shore of Foveaux Strait certain species of *Acaena* are abundant and there are many silvery patches of *Raoulia australis* and *R. Beauverdii*; tussocks of *Poa caespitosa* also are plentiful. *Pimelea Lyallii* replaces *P. arenaria*, and other plants not found on dunes further N. are *Geranium sessiliflorum* var. *glabrum*, *Wahlenbergia congesta* and *Gnaphalium trinerve*.

e. Hollows and sand-plains.

An advancing dune-ridge leaves, in its wake, flat sandy ground which may continue to be further hollowed out by wind-action, until moisture rising from the water-table damps the surface-sand and stops further sand-movement. Such a hollow is quite stable and ready for occupation by non-psammophytes.

The final destiny of such areas does not depend upon their plant-covering but on the stability of the adjacent dunes. Thus one of two things may happen, — there may be an invasion of sand and reversion to dune-conditions, certain associations arising only to be destroyed, or there may be a long stage of stability and a succession of associations culminating in a climax-association.

In the Eastern, Ruahine-Cook, Egmont-Wanganui and, at times, the North Auckland districts the first-comer on the damp sand is *Gunnera arenaria* which forms circular mats 80 cm — 2 m in diam., the small, thick, pale-green or brownish leaves flattened to the ground. *Scirpus cernuus*, *Ranunculus acaulis*, *Epilobium Billardieranum*, *E. nerteroides*, *Crantzia lineata* and especially *Carex pumila* are characteristic. *Lobelia anceps*, *Limosella aquatica* and *Myriophyllum Votschii* are abundant in the N. and C. Should there be no invasion of sand certain common halophytes next occupy this non-halophytic station, e. g., *Selliera radicans*, *Samolus repens* var. *procumbens*, *Cotula coronopifolia*, *C. dioica* or some of its allies, and the species of *Apium*. Finally the rush-like *Leptocarpus simplex* will perhaps take complete possession of the ground. On the

N. shore of Foveaux Strait *Raoulia australis* may be plentiful, and in the North Auckland district *Eleocharis neo-zealandica* builds slightly raised patches.

If the hollow does not become moist, *Carex pumila* early takes possession, increasing at a great rate through its far-creeping rhizome. A rapid drift favours *Spinifex* in the N. and C.; it quickly builds multitudes of low, rounded mounds.

f. Sand-heath.

Generally at some distance inland, but occasionally just beyond the fore-dune, the sand-hollows may be closely covered by heath with *Leptospermum scoparium* dominant (Plate VI Fig. 8). In the North Auckland district many species of the gumland heath may be present, especially — *Leptospermum lineatum*, *Pomaderris phylicaefolia*, *Styphelia fasciculata*, *S. Fraseri* and *Pimelea prostrata*. *Cassinia retorta* will be in abundance and there will be more or less *Mariscus ustulatus*, *Phormium tenax* and *Arundo conspicua*.

On the northern shore of Cook Strait, *L. scoparium* often forms a closed association, especially where the surface is wet, when certain swamp-plants will be present, e. g. — *Eleocharis Cunninghamii*, *Carex ternaria*, *Potentilla anserina* var. *anserinoides* and *Coprosma propinqua.*

g. Ancient dunes.

Ancient sand-hills occur in the South Otago district near the Bluff Estuary and along the lines of the ancient straits of Stewart Island. The Bluff dunes are separated from the Estuary by *Sphagnum* moor. They are covered with *Danthonia Raoulii*-steppe, and the following non-dune, frequently subalpine plants, are present: — *Blechnum penna-marina*, *Lycopodium fastigiatum*, *Gaultheria perplexa*, *Helichrysum bellidioides*. The Stewart Island dunes bear a heath-vegetation, as follows: — *Leptospermum scoparium* (dominant), *Gleichenia dicarpa* (abundant), *Pteridium esculentum*, *Lycopodium ramulosum*, the creeping alpine taxad *Dacrydium laxifolium*, *Cladium Vauthiera*, *Phormium Cookianum*, *Enargea parviflora*, *Styphelia Fraseri*, *Pentachondra pumila* and *Coprosma repens*. The alpine character of this combination is remarkable.

h. Dune-forest.

Forest is rare on the dune-area. Swampy sand-plain may occasionally contain *Podocarpus dacrydioides* forest. Various coastal and inland-coastal trees occur in dune-gullies and sheltered hollows in the North Auckland district and on the N. shore of Cook Strait, e. g. — *Macropiper*, *Knightia*, *Corynocarpus* and *Myoporum*. On the lee-slopes of the high western dunes of Stewart Island, there is a luxuriant low forest in which *Griselinia littoralis* and *Metrosideros lucida* dominate. Very similar forest occurs on the dunes in the S.E. of the S. Otago district. On the ancient dunes near the Ruggedy Mts., Stewart Island, according to POPPELWELL (T. N. Z. I. 1913: 283) there is *Dacrydium cupressinum-Weinmannia* forest.

8. Rock and Cliff.

a. General.

Rock-surfaces are common on the coast and vary from high vertical cliffs, their bases washed by the waves, to flat sea-worn rocks hardly raised above the water. According to the nature and aspect of the rock most diverse stations are available for plant-life. On a vertical wall of hard rock with an even surface exposed to a maximum of salt-spray, there are no plants except a few lichens, but a sheltered rock in a rainy locality with many cracks, crevices and ledges, where soil can lodge, will support a rich vegetation.

Although rock-associations are at first open, rooting-places are so limited in area, that there may be keen competition between the early comers. The soil-making ability of the plants may have much influence upon the ultimate composition of the association, certain peat-formers being able to furnish a soil of considerable depth and great water-holding capacity. Chasmophytes cannot gain a footing, until there be sufficient soil in the cracks or crevices. This may consist of small rock-fragments and sand weathered *in situ*, or blown soil. Accumulations, 2.5—5 cm in depth, are quite frequent. The seedlings must be able to tolerate periods of drought. Succulency, thick coriaceous leaves, prostrate and rosette-forms are frequent and advantageous. Often the roots form a mat, as with certain rock-ferns, while even long roots may at first extend laterally along a fissure.

It is not easy to draw the line as to true coastal-rock formations. Thus, at Jackson Bay, Westland, there is an isolated rock, only to be reached at low-water, 3—4 m high, on the flat top of which grows a collection of forest-mesophytes, while in peat, on its face, is a dense mat of *Enargea*, a denizen of wet subalpine, or sometimes lowland forests.

Besides true coastal chasmophytes, the rock-vegetation includes more inland species than any of the other shore-formations. Even lianes are not wanting, their sub-xerophytic structure, such as it is, being of advantage for the severe conditions of the open. True alpine plants may be present, some of which are found in no intermediate station (*Celmisia Lindsayi*, *C. Monroi*, *C. semicordata*).

Rather more than 100 species of vascular plants belonging to 37 families may be considered more or less common on rocks at various parts of the coast, but of these only 20, at most, occur where there is noticeable sea-spray, and hardly one can be termed an "obligate" rock-plant. Many of these species are halophytes from salt-meadow or salt-swamp, others are heath-plants and some come from the neighbouring forest or scrub.

b. Mesembryanthemum cliff.

M. australe is the most characteristic plant of exposed coastal-cliffs being absent only in the Subantarctic province. It forms bright green patches, the shoots hanging downwards and not rooting, so that they can be raised like a curtain. But roots are produced on flat or creviced rocks (Plate VI Fig. 9). Where exposed to the maximum of spray the *Mesembryanthemum* may be the sole plant, but throughout the Northern, Central and Southern provinces, it is frequently accompanied by *Salicornia australis*, *Apium prostratum* and *Senecio lautus*. In the N. and C., *Coprosma Baueri*, as a prostrate shrub hugging the rock, is common, while in the N. there are often isolated plants, or extensive colonies, of the liliaceous herb, *Arthropodium cirrhatum*, conspicuous with its broad, thick, pale-green leaves some 60 cm in length. The fern *Asplenium obtusatum*, an occasional plant of the association in the N. and C., is abundant in the S.

With less spray, other plants enter in and *Mesembryanthemum* becomes of decreasing importance. Rocks of many shapes, the outcome of much weathering, standing at various distances from the water, obviously offer much more varied conditions than a high wall-like cliff, and so possess a richer flora. The following are frequently present: — *Polypodium diversifolium*, *Cyclophorus serpens*, *Arundo conspicua* (especially in the N.), *Poa anceps* (var. *condensata*), *Agropyrum multiflorum*, *A. scabrum*, *Scirpus cernuus*, *S. nodosus*, *Cladium Sinclairii* (N.), *Leptocarpus simplex*, *Phormium tenax*, *Muehlenbeckia complexa*, *Rhagodia nutans* (but not S. of Banks Peninsula), *Colobanthus Muelleri*, *Lepidium oleraceum*, *Crassula moschata* (S.), *Linum monogynum*, *Coriaria ruscifolia*, *Pimelea prostrata*, *Leptospermum scoparium*, *Samolus repens* var. *procumbens*, *Lobelia anceps* (N. C. and S. to Banks Peninsula and Okarito), *Selliera radicans*, *Lagenophora pumila*, *Sonchus littoralis*, and one or other of the species of *Cassinia*.

The following 2 plants are restricted in distribution but it is probable that together with many of the above they form definite sub-associations: — *Hymenanthera crassifolia* (virtually confined to the vicinity of Cook Strait and southwards on the E. to North Otago); *Coprosma Kirkii*, a prostrate shrub with long, flexible, straggling branches and small, thick, glossy bright-green leaves (chiefly in N. of N. Auckland district, but also recorded from the Egmont-Wanganui, Ruahine-Cook and E. Cape districts).

c. Pohutukawa (*Metrosideros tomentosa*) *cliff.*

Specially characteristic of northern New Zealand and magnificent when loaded at about Christmas with their crimson blossoms are the long lines of that massive tree *Metrosideros tomentosa*, jutting from the faces of coastal cliffs, its spreading branches extending outwards over the rocky shore, at times almost dipping into the water. The frequently almost horizontal position of the tree, the great weight of trunk and crown, together with the resistance this latter offers to the wind, demand efficient means of fixing to the rock. This is met by the tree's innate power to put forth abundance of aerial roots (Plate XIV and Figs. 2 and 10), which spread over the cliff-face and send down branches deep into the rock.

The association is made up of a considerable number of species and growth-forms, in fairly sheltered positions, but with increase of wind and spray, only the true coastal plants remain. *Astelia Banksii*, in pure colonies, is abundant on the rock-face. The thick, stiff, linear, tapering leaves, 1.4 m long, dark-green above and silvery beneath are in great tufted masses. Thick masses of dead leaf-bases surround the living leaf-sheaths and function as a water-holding and food-containing apparatus. *Peperomia Endlicheri*, a succulent herb, which spreads by means of its far-creeping stems, is abundant, both as an epiphyte and on the rock. The ferns *Asplenium lucidum*, *Polypodium diversifolium* and *Cyclophorus serpens* are often common. *Arthropodium cirrhatum*

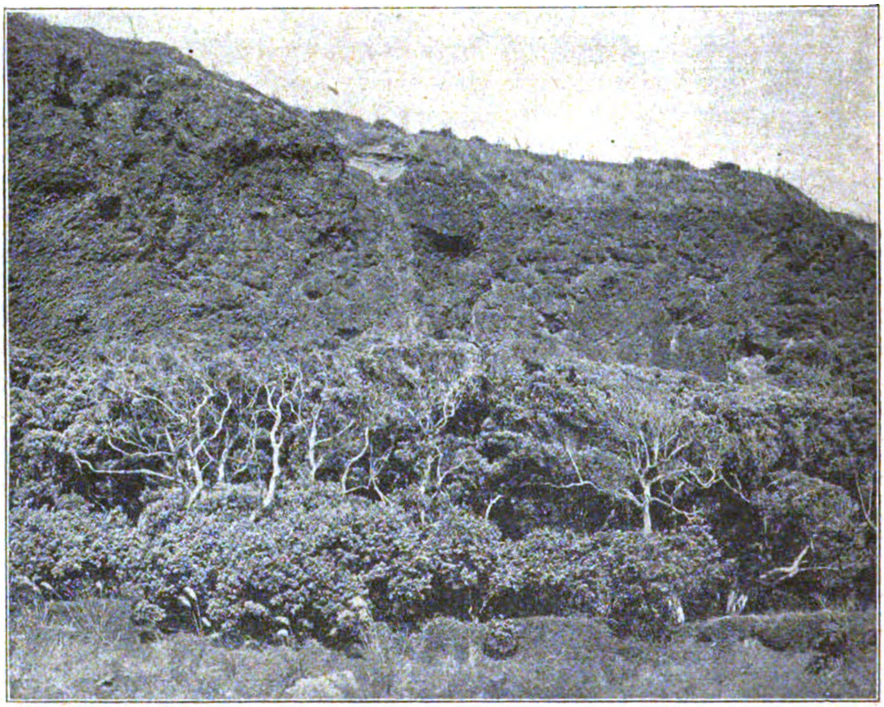

Fig. 10. Belt of *Metrosideros tomentosa* on sandy ground below cliff; west coast of Auckland to N. of Waitakarei River. North Auckland botanical district. Photo L. Cockayne.

may be so abundant as to cover the rock with greenery for many square metres. Mats of *Poa anceps* var. *condensata* are often frequent. The shrubs, *Coriaria ruscifolia*, *Leptospermum scoparium*, *Pseudopanax Lessonii*, *Veronica macrocarpa*, *V. salicifolia*, *Olearia furfuracea* and *Brachyglottis repanda* may be more or less common, and so too, *Arundo conspicua*, *Phormium tenax*, *Rhagodia nutans*, *Mesembryanthemum australe* with its accompanying halophytes, as well as other coastal, forest or scrub plants, according to the degree of shelter.

If the cliffs are much more exposed than the above, many of the species cited are absent and *Metrosideros tomentosa* will decrease in quantity, until, on the most exposed cliffs, it is wanting.

d. Phormium Cookianum association.

Phormium Cookianum is a common feature of coastal cliffs in the E. of the Central province and it extends S. to the North-Eastern district and on the W. to Stewart Island. The coastal plant differs somewhat from the subalpine forms. The leaves crowded and bunched together are about 1.4 m long by 9 cm broad, the lower half of each is erect, owing to the sides of the blade being pressed together, but the upper half droops downwards. In many localities a spreading semi-prostrate or prostrate *Veronica* may be present; in others the *Phormium*, *Coprosma Baueri*, *Poa anceps* var. *condensata* and various halophytes form the association. On East Cape Island a species of *Plantago* is common with fleshy green leaves in rosettes 21 cm in diam.

1. Veronica macroura sub-association.

V. macroura is a shrub of spreading, drooping habit, the stems leafy near the extremities only, the leaves moderate-sized, rather broad and the flowers white and sweet-scented. Ecologically similar is *V. Atkinsonii* of the neighbourhood of Cook Strait and the Marlborough Sounds.

On the soft shale cliffs of the East Cape district, the yellowish-green clumps of *P. Cookianum* are dominant. *V. macroura* is abundant and it may grow through the frequent mats of *Poa anceps* var. *condensata* and hang down the cliff-face. Other associated plants are: — *Scirpus nodosus*, *Apium prostratrum*, *Samolus* and probably other halophytes, *Lobelia anceps*, *Lagenophcra pumila*, *Cassinia leptophylla*, *Senecio Banksii*, *S. Colensoi* and *Sonchus littoralis*. In sheltered gullies the *Veronica* is erect and there may be a close growth of *Arundo*, *Coriaria ruscifolia* and the *Phormium*.

On the northern shores of Cook Strait the rock is much harder; there is great variety of stations and accompanying variety of species. *Phormium Cookianum* accompanied by *Veronica Atkinsonii* is common in many places making a well-defined association. But alongside, or connected by transitions, are combinations to be referred rather to *Mesembryanthemum*-cliff, while in places a species or group of such appears that seems out of place.

The sub-association here varies in composition according to the light-relation. Where much shaded and moist there is a considerable number of species some of which are quite unexpected (*Aciphylla squarrosa*, *Craspedia robusta* var. and *Senecio lagopus*). *Festuca multinodis* forms dense deep mats; *Mesembryanthemum*, *Linum monogynum*, *Asplenium flaccidum* and *Cyclophorus serpens* are abundant. With increase of light and greater distance from the sea many of the above are wanting and shrubs appear (*Macropiper*, *Leptospermum scoparium*, *Brachyglottis repanda*). On very dry, rapidly disintegrating greywacke there is little except *Raoulia australis* and *Pimelea prostrata*. On isolated rocks near Cape Turakirae (ASTON T. N. 2. I., 1912: 212) the usually epiphytic *Dendrobium Cunninghamii* makes a thick mat and other orchids of the same class are present (*Sarcochilus adversus*, *Bulbophyllum pygmaeum*).

Rock-faces in the Marlborough Sounds, though furnished abundantly with *P. Cookianum* and *V. Atkinsonii*, are distinguished by the presence in plenty of *Arthropodium cirrhatum*, *Griselinia lucida* and *Astelia Solandri*, the two latter being also abundant on rocks to the S. of Kaikoura (North-eastern district). Also the following shrubs, amongst others, are present: — *Coriaria ruscifolia*, *Leptospermum scoparium*, *Rapanea Urvillei*, *Olearia Forsteri*, *Cassinia leptophylla* and *Brachyglottis*.

2. Olearia insignis sub-association.

This plant-community is present on most of the cliffs of the North-eastern district from about the Amuri Bluff northwards. It is not essentially coastal, but in a slightly changed form, extends for many kilometres inland up the river-valleys. *O. insignis* is a stout low-growing shrub of straggling habit. The sparsely-branching stems are grey or black, exceedingly stiff and bear at the extremities short, open rosettes of 6—7 obovate, thick, fleshy leaves each about 9.5 cm long, shining green above, and beneath clad with densc, felt-like, buff tomentum. The roots pass far down into the rock. The shrub grows on the dryest and steepest rock-faces. *Phormium Cookianum* is very abundant, but it is dominant only on more shady rocks, or where there is some amount of débris. Other species are: — *Cyclophorus serpens*, *Linum monogynum*, *Angelica Gingidium*, *Veronica Hulkeana* (at times, but beyond the influence of spray) and occasionally *Senecio Monroi*.

e. Coastal-fern association.

This occurs only in the southern part of the Southern botanical province, where the climate favours the formation of raw humus, even on a steep rock-surface. This is favourable for close settlement, but unfavourable for the well-being of most species. In consequence the association is clearly defined.

The littoral ferns, *Asplenium obtusatum*, *Blechnum durum* and sometimes *B. Banksii*, are dominant, and may be the sole species, especially in a feeble light. *Myosotis albida*, a coastal herb with thick, soft, hairy leaves in erect rosettes, also a peat-maker though never abundant, is frequently present. *Veronica elliptica* is a common shrub, but it is not dependant on the peat and is a chasmophyte. The tussocks of *Poa Astoni* are very characteristic. In the shade they droop, with leaves 30 cm or more in length, but, where fully exposed, are smaller and erect. The small, succulent, reddish *Crassula moschata*, a spray-tolerator, is common and one of the pioneer plants. When soil becomes abundant certain coastal-moor plants (especially *Scirpus aucklandicus*, *Plantago Hamiltonii*, *Gentiana saxosa* and *Cotula pulchella*) and the usual halophytes gain a footing.

f. Rock-associations of local occurrence.

1. Sand-eroded rock, N. coast of Cook Strait.

Between the Rivers Waitotara and Wangaehu much rock, at a short distance from the coast, has been cut into fantastic forms by wind-borne sand, an extremely xerophytic station being thus provided. The association consists partly of dune-plants (*Festuca littoralis*, *Coprosma acerosa*) and partly of semi-subalpine species (*Raoulia australis*, *Pimelea prostrata*). In some places S. of the R. Wanganui are larger, flatter rock-surfaces on which are the remains of perhaps a rather ancient plant-covering consisting of — *Myoporum laetum*, *Dodonaea viscosa*, the small forest-tree *Rapanea Urvillei* and the divaricating frequently subalpine *Corokia Cotoneaster*.

Where the rock is cut to a base-level a flat stony desert results. The rock-floor is strewn with sand-worn stones and there is a thin covering of small gravel and coarse sand. *Pimelea prostrata* and *Coprosma acerosa* are dotted about everywhere in equal numbers (Plate VII Fig. 11), and, in the lee of the latter, there is generally a tongue of sand (Plate VII Fig. 12). Silvery cushions of *Raoulia australis* occur here and there; *Spinifex* and *Scirpus frondosus* form lines where the sand is finest; there are colonies of *Zoysia pungens* and yellow cushions of *Scleranthus biflorus*.

2. Celmisia semicordata association (Charleston, North-western district).

At one spot on the coast, the prevailing westerly wind, hemmed in by two adjacent headlands, strikes the summit of the cliff and its immediate vicinity with especial force. In consequence, the subtending girdle of forest is first dwarfed and then broken through. The rocks at a little distance from the edge of the cliff possess a plant-covering physiognomically more like that of subalpine rocks than of the coast. The moist climate favours the formation of peat on the rock; possibly a certain amount of spray is carried by the wind but it must be soon washed from the soil. The subalpine *Celmisia semicordata* is abundant. Other plants present, frequently subalpine, are: — *Oreobolus pectinatus*, *O. strictus*, *Phormium Cookianum*, *Pimelea longifolia*, *Styphelia empetrifolia*, *Olearia avicenniaefolia* and *Senecio bellidioides*. Several plants of the adjacent heath are present and stunted forest-trees and lianes; the coastal element is represented by *Asplenium obtusatum*, *Scirpus nodosus*, *Plantago Hamiltonii* and *Senecio rotundifolius*[1]).

3. Celmisia Lindsayi association.

This is confined to cliffs in the South Otago district from Nugget Point southwards. The cliffs and rocky slopes, where there is soil or débris, are occupied by *Metrosideros lucida*-forest, *Leptospermum*-thicket or *Veronica elliptica-Phormium tenax* scrub. The *Celmisia*-association is quite distinct from those. It is situated on the solid rock-face, or the youngest débris, and so is the first of a series of associations terminating in forest. *Celmisia Lindsayi* (Plate VIII Fig. 13), forming circular patches 90 cm, or more, in diam. is domi-

1) Mr. D. Petrie informs me that he refers this plant to *S. elaeagnifolius*. H. J. Matthews, and few knew New Zealand plants better from the gardener's standpoint, i. e. recognized trivial distinctions, did not hesitate to name it *S. rotundifolius*.

nant. *Anisotome intermedia*, its leaves 76 cm or more in length, is a companion plant, but seems to prefer the débris as a station. Tussocks of *Poa Astoni*, on the rock, and *Hierochloë redolens*, on the débris, complete the association. Further to the S., the *Celmisia* may be absent, but the *Anisotome* continues on cliffs to beyond Curio Bay.

4. Okarito Bluff.

The substratum consists of old morainic material. Where water drips there are great sheets of *Gnaphalium trinerve* and in places *G. Lyallii*. The liane *Metrosideros scandens*, clinging closely to the cliff, occupies many square metres. *Blechnum capense*, the fronds hanging downwards, forms extensive colonies. The following shrubs occur, both as a wind-shorn scrub and dotted about — *Coriaria ruscifolia*, *Melicytus ramiflorus*, *Fuchsia excorticata*, *Rapanea Urvillei*, *Veronica salicifolia*, *V. elliptica*, *Coprosma lucida* and *Olearia avicenniaefolia*. *Arundo conspicua* and *Phormium tenax* are common. Besides several ordinary herbaceous halophytes, the following herbs or grasses are present: — *Asplenium lucidum*, *Poa Astoni*, *Gunnera albocarpa*, *Nertera depressa*, *Lobelia anceps*. At the base of the cliff, on the débris, is *Paesia scaberula* and *Euphorbia glauca*.

5. Cliffs S. W. of Stewart Island.

The vegetation of these cliffs is called attention to because they are the station of *Celmisia rigida* and *Anisotome flabellata*, two endemic Stewart Island plants. *C. rigida* grows in peaty ground on the summit of the cliffs. The *Anisotome* is a chasmophyte confined to rock. Its roots are of an extraordinary length. The pale-green, pinnate, thick, fleshy leaves, 2.5 cm long, are in small rosettes, which, pressed closely together, are flattened to the rock.

6. Rock-débris associations.

In the neighbourhood of Cook Strait, Wellington, and on Kapiti Island there are coastal slopes of stony débris. The stones are angular and vary in size from pieces some 16 cm × 12 cm to small fragments mixed with coarse sand. Although the surface is generally quite dry, at 5 cm deep there is always a considerable amount of moisture. W. of Island Bay, where the neighbouring slopes are occupied by tussock-steppe, the débris has an open vegetation consisting of *Poa caespitosa* where most consolidated, *Muehlenbeckia complexa* as a mat, *Acaena novae-Zealandiae*, *Epilobium novae-Zealandiae*, *Aciphylla squarrosa* and *Calystegia Soldanella*.

The Kapiti Island débris-slope is frequently quite bare, but, elsewhere, it is occupied by an open association of heath-plants, e. g. — *Arundo conspicua*, *Muehlenbeckia complexa* and *Cassinia leptophylla* (Plate IX, Fig. 14).

9. Coastal Scrub.

By "Scrub" I mean a close growth of shrubs or stunted trees one or both. On the coast, its presence denotes excess of wind combined with much rain, or a dry station with abundant precipitation. In places, it is hardly possible to draw the line between forest and scrub, for forest exposed to frequent violent wind becomes scrub. On the other hand, tall scrub may be virtually forest.

Scrub of a definite character containing species rare or wanting elsewhere is found chiefly in the Stewart and Fiord districts, where it often forms a narrow girdle along the shore in front of the rain-forest.

a. Mutton-bird[1]) (*Tree-composite*) *scrub.*

This consists of the two sub-associations, *Senecio-* and *Olearia*-scrub. The following are the principal constituents: *Phormium Cookianum*, *Leptospermum scoparium*, *Metrosideros lucida*, *Dracophyllum longifolium*, *Veronica salicifolia*, *V. amabilis* var. *blanda*, *V. elliptica*, *Olearia operina*, *O. angustifolia*, *O. Colensoi* and *Senecio rotundifolius*.

1. Senecio rotundifolius sub-association.

This forms a girdle varying in width according to the wind-velocity round the inlets and sheltered parts of the Stewart Island coast and in portions of the Fiord district, but with a somewhat different composition. It extends from the margin of the rain-forest almost to high-water mark. The soil is often shallow peat overlying soft granite, but when the scrub faces a sandy or gravelly shore and there is no cliff adjacent, the soil is deeper and wetter. *Senecio rotundifolius* is dominant. It is about 3 m high and frequently prostrate in part (Fig. 15). The numerous, stout, rigid, naked branches covered with smooth brownish bark spread widely and form, through their final branching, a rounded head of stiff branchlets covered with the large round leathery leaves, bright shining green above but beneath clad with buff tomentum. The intermingled crowns make a flat roof which is penetrated, here and there, by the yellowish fastigiate heads of the *Dracophyllum*, its long, needle-like leaves arranged vertically. Sometimes, close to the front, are thick green masses of *V. elliptica.* Still further to the front, but absent over wide areas, is the *Phormium*, its broad, green leaves almost drooping into the water. Just behind the scrub proper, though frequently extending long arms above it, are irregular-shaped trees of *Metrosideros lucida.*

Where the wind strikes with greater violence, *Leptospermum scoparium* appears and increases in amount with increase of wind-intensity, becoming by degrees of lower stature until, as a wind-shorn shrub, it takes the front position on rocky headlands (Fig. 1). On the other hand, where there is complete shelter the *Senecio* sub-association is absent, the mesophytic small forest-trees, shrubs and ferns coming to the front. Within the scrub there is an entanglement of prostrate trunks and branches. The ferns *Asplenium obtusatum* and *Blechnum durum* grow on the peaty floor.

1) So well-marked is this association that it has received this name from the settlers since it covers those islands where the petrel (*Puffinus griseus*) breeds, a bird highly-esteemed by the Maoris for food.

2. Olearia sub-association.

Dominance of *Olearia* denotes a more exposed station than does that of *Senecio*. The species of the genus cited above belong to a section distinguished by their large flower-heads with rays or discs purple in some species and stiff, toothed, more or less lanceolate leaves covered beneath with white adpressed tomentum. *O. angustifolia* and *O. Traillii* when fully developed are actually trees (Plate XI, Fig. 16).

The sub-association is strongly xerophytic, a condition demanded by its position on headlands and islets fairly in the track of the frequent, violent, cold subantarctic gales, which, at times spray-laden, strike the plants and saturate the shallow, porous soil. It is astonishing how, in such a station, where nanism would appear the response requisite, thick, stiff, tomentose leaves, in rosettes, rigidity of branches and a dense globular growth-form, permit the presence of small trees and, in the case of *O. Colensoi*, broad leaves, 18 cm long. There are two distinct forms of *Olearia*-scrub according as *O. angustifolia* or *O. operina* dominate.

Olearia angustifolia-scrub.

This is common on the most exposed parts of the coast of the Stewart district; there is also a small piece at the base of the Bluff Hill. Seen from a distance, the scrub is defined by its sage-green colour. Where most exposed, it consists of *O. angustifolia* and *O. Colensoi*[1]) with perhaps a few plants of *O. Traillii* and on certain islets *Senecio Stewartiae*. Generally, the shrubs are prostrate, but the branches eventually curve upwards. Within there is a tangle of rigid stems. The coastal ferns are the sole floor-plants, but much is bare.

A transition between *Senecio* and *Olearia* scrubs occurs at Mason Bay and on Codfish Island. The general character is much as already described, but the sage-green colour is relieved by green patches of *Griselinia littoralis*, especially at some distance from the sea. Where sufficient light penetrates, there are great colonies of *Stilbocarpa Lyallii*, which spread for many metres, thanks to its vegetative increase by means of arched runners. The bright-green, shining, thin leaves each 30 cm, or more, in diam. stand on long stalks, 90 cm above the ground.

Olearia operina scrub.

This plant-community, confined to the Fiord district, is distinguished from the other scrubs, already defined, by the presence of *O. operina*, the absence of *O. Colensoi*, and when in its more sheltered positions a greater abundance of forest mesophytic trees or shrubs[2]), which latter may form a distinct girdle. Its northern limit appears to be Big Bay (Fiord district).

1) This may be *O. Lyallii* (see COCKAYNE 1909e: 63).

2) Principally *Pittosporum Colensoi* var. *fasciculatum*, *Coriaria ruscifolia*, *Aristotelia racemosa*, *Fuchsia excorticata*, *Nothopanax Colensoi* and *Pseudopanax crassifolium* var. *unifoliatum*.

b. Veronica elliptica-scrub.

At various localities in the Otago fiords, on the shores of Foveaux Strait, in Stewart Island and in a modified form at Otago Harbour, there is a scrub in which *V. elliptica* dominates, but such is not of uniform composition. The following are examples: At Anita Bay, Milford Sound, the upper shingly strand rises into a low terrace, above the loose stones of which spread out the branches of *V. elliptica*, *V. salicifolia* and *V. amabilis* var. *blanda*. These shrubs form a natural hedge, densest where *V. elliptica* dominates, but more open where the rather straggling *V. salicifolia* occurs.

At the base of the Bluff Hill, besides *V. elliptica* 1.8—2.4 m high, *Olearia arborescens*, *Nothopanax arboreum*, *Fuchsia excorticata* and *Aristotelia racemosa* are more or less common, and there is a little *V. amabilis* and *Melicytus lanceolatus*. Beneath the shrubs are *Astelia nervosa* and the coastal ferns.

On the larger of the Open Bay Islands, in one place, at any rate, is a scrub of *V. elliptica* (a large-leaved form) 4 m high, over which climbs *Muehlenbeckia australis* while beneath is *Astelia nervosa*, *Histiopteris incisa* and *Asplenium obtusatum*. The soil is deep, coarse peat.

V. elliptica itself extends to Titahi Bay, Wellington as a distinct variety, but from a little to the N. of Dunedin it is wanting on the E. of the South Island. Though it forms small patches of scrub together with certain forest-plants it is frequently a rock-plant.

c. Scrubs of local distribution.

1. Liane-scrubs.

Freycinetia-scrub.

Close to high-water mark on the W. coast of the South Island the rigid stems of *F. Banksii* creeping on the ground, in places, form an entangled mass. The richest development of this curious scrub is on the more northerly of the Open Bay Islands (Western district). It is about 2 m high and of an extreme density. The stout stems each 12 cm in circumference, bearing an abundance of thick, yellowish-green, sword-shaped leaves, are twisted in all directions, and interwoven, thus forming a rigid entanglement. The density is often increased by an admixture of the lianes *Muehlenbeckia australis* and *Calystegia tuguriorum*.

At the bottoms of sea-cliff gullies of the North-western district the same association occurs, but as a different community, the shrubs, *Melicytus ramiflorus*, *Coprosma lucida*, *Olearia avicenniaefolia* and *Senecio rotundifolius* being present.

Muehlenbeckia-scrub.

Where clay hillsides slope shorewards (Banks Peninsula, S. Wellington &c.), there may be many rounded or pyramidal bushes of *M. complexa*, the dark, wiry stems intertwined. Such liane-shrubs are dotted about or intermingle.

Scrub consisting of *M. australis* occurs on the more southerly of the Open Bay Islands. The plants, sometimes mixed with the fern *Histiopteris incisa*, grow into one another making dense thickets.

Liane-scrubs frequently denote the existence of former forests, and in the case of the Open Bay Islands afford strong evidence of former connection with the mainland (see COCKAYNE 1905 c: 373, 374).

Urtica-Muehlenbeckia-scrub.

On the beach near Nugget Point, South Otago district, there is a dense thicket of the shrubby nettle, *Urtica ferox* together with the ferns *Pteridium esculentum* and *Dryopteris punctata* and the shrubs *Melicytus ramiflorus* and *Fuchsia excorticata*, *Muehlenbeckia australis* binding the whole into a close mass. A similar scrub, but with fewer members, occurs on Centre Island, Foveaux Strait and probably on some of the other islands of the Stewart district.

2. Forest-scrub.

Here are included those collections of forest-plants which are prevented from developing into forest through powerful coastal winds or other agencies. Between this vegetation-form and wind-shorn forest there is merely a difference in height and density. Certain species respond more readily to wind-stimulus than do others, and such a quality may be considered a specific-mark.

Pohutakawa (Metrosideros tomentosa scrub).

α. West coast of N. Auckland district.

In front of the cliffs to the N. of the Manakau Harbour the usual coastal forest is represented by scrub. Where there is a stony terrace with a soil of shallow clay the composition of the association may be somewhat as follows: — *M. tomentosa* (dominant), *Cordyline australis*, *Macropiper excelsum*, *Pittosporum crassifolium*, *Corynocarpus laevigata*, *Pseudopanax Lessonii*, *Coprosma grandifolia*, *C. Baueri*, *Brachyglottis repanda* (Fig. 10).

β. Rangitoto Island. (Plate XII, Fig. 17).

Rangitoto Island is an ancient volcano situated in the Hauraki Gulf, more or less circular in form, about 6 km in diam. and from its centre rises the scoria cone some 270 m high surrounding which is an extensive lava-field made up of blocks of scoria of all sizes piled upon one another and full of gullies, hollows and chasms. There is no visible water on the island, the rain passing at once through the open substratum, though some must be absorbed by the porous rock. Notwithstanding the apparently inhospitable nature of the habitat, more than 180 species of indigenous spermophytes and pteridophytes occur on the island, and although bare patches are frequent enough, there are not merely rock-plants present but both open and closed scrub and even forest. Every stage of plant-colonization also can be seen, from occupation of rock by lichens, liverworts, mosses and even *Hymenophyllaceae*, to actual forest. But on the island generally the trees remain at the shrub-stage, blooming and fruiting abundantly.

Almost any of the plants appear capable of settling upon the naked lava. This could well be expected of the following epiphytes, or rock-plants: — *Metrosideros tomentosa* (the dominant species of the island), *Astelia Banksii*, *A. Cunninghamii* var. *Hookeriana*, *A. Solandri*, *Metrosideros lucida*, *Griselinia lucida* (Plate XII, Fig. 17) and *Senecio Kirkii*. But it is hardly to be anticipated in *Coriaria ruscifolia*, *Geniostoma ligustrifolium*, *Veronica salicifolia*, *Coprosma robusta* and *C. lucida*. All the above may grow into one another and make a close low scrub. Other common shrubs are: — *Knightia excelsa*, *Nothopanax arboreum*, *Rapanea Urvillei* and *Styphelia fasciculata*[1]).

γ. White Island.

White Island is a small cone in the solfatara stage, 2.4 km in diam., 328 m high, situated in the Bay of Plenty and distant from the mainland 48 km. From its crater pass off great clouds of steam highly charged with HCl. It is the presence of this gas, according to R. B. Oliver, that governs the distribution of plant-life on the island, since where the fumes strike there is complete absence of vegetation. In foggy weather, the same observer graphically states, "it may be said to rain dilute Hydrochloric acid".

The total number of species of vascular plants on the island is only 12 which include as shrubs only *Metrosideros tomentosa* and *Coprosma Baueri*. The former makes a high scrub at the western end of the island varying from 3 or 4 m to 6 or 8 m in height where most luxuriant. The shrubs or low trees grow closely, their dark-green foliage being confined to the roof. Dead branches and twigs attached to the living plants are a conspicuous feature and it is evident that the association has no easy task to hold its own[2]).

δ. Southern botanical province.

On the summit of the isthmus connecting Nugget Point and the mainland in the S. Otago district, there is a scrub, 1 m high, having a sloping roof, so dense that one can walk upon it, nor can the plants be disentangled without using force. The composition, as follows, shows it to be merely depauperated forest: — *Podocarpus totara*, *Drimys colorata*, *Carpodetus*, *Fuchsia excorticata*, *Coprosma propinqua*, *C. foetidissima* and the lianes, — *Muehlenbeckia australis*, *Raoulia australis*, *Fuchsia Colensoi* and *Parsonsia heterophylla* which bind the shrubs tightly together.

At various points on the W. coast of the South Island there is forest-scrub. In the North-western district species of *Nothofagus* play a considerable part. Near Point Elizabeth, in the same district, *Brachyglottis repanda* is in evidence.

1) This brief sketch does scant justice to what is perhaps the most remarkable piece of vegetation in New Zealand.

2) This account of White Island is summarized from a paper Mr. Oliver has prepared on its vegetation and which he generously allowed me to use.

On the face of gravel terrace near Hokitika (Western district) the members are, — *Dicksonia squarrosa*, *Muehlenbeckia australis*, *Coriaria ruscifolia*, *Weinmannia racemosa*, *Fuchsia excorticata*, *Melicytus ramiflorus*.

10. Coastal Heath.

Very little need be said on this head. *Leptospermum scoparium*, its allies and the species of *Cassinia* are the special heath plants, but the association is generally similar to that of dune-hollow for the same locality. On certain parts of Bluff Hill (South Otago), *Cassinia Vauvilliersii*, *Styphelia acerosa*, *Leptospermum scoparium*, *Weinmannia racemosa*, *Coprosma propinqua* and *C. parviflora* form the bulk of the heath.

11. Coastal Forest. (Plate XIII, Fig. 18).

a. General.

Forest cannot exist under severe coastal conditions. This is well seen in Paterson Inlet (Stewart Island) where the arborescent shore-covering reflects the wind-intensity, mesophytic taxad-forest with its hygrophytic interior denoting the minimum and xerophytic *Leptospermum*-scrub the maximum. (Plate I Fig. 1).

In many places coastal-forest does not differ greatly from that of the adjacent lowlands, except in the greater abundance of wind-tolerating members which may form a seaward girdle.

As already seen the coastal trees number 28, but only the following are at all common and some of these limited to some special part of the coast: — *Macropiper excelsum*, *Pittosporum crassifolium*, *P. umbellatum*, *Corynocarpus laevigatus*, *Dodonaea viscosa*, *Entelea arborescens*, *Metrosideros tomentosa*, *Pseudopanax Lessonii*, *Myoporum laetum*, *Coprosma Baueri* and *Olearia Forsteri*[1]).

The special coastal-tree associations are most in evidence in the Northern province and become less marked the further S. one proceeds. Few of the trees can tolerate more than a few degrees of frost, and when it is remembered that nearly all the genera are palaeotropic, while 6 species extend to countries warmer than New Zealand, it seems highly probable that the coastal tree-florula is but a remnant of one much larger and that the species frequent the shore-line rather on account of the mild maritime climate than through possessing special adaptations. On the other hand, in parts of the S. where special coastal trees are absent the shoreward face of a forest frequently consists of a girdle of wind-tolerating and more or less spray-enduring species, e. g. — *Carpodetus serratus*, *Pittosporum tenuifolium*, *Pennantia corymbosa*, *Weinmannia racemosa*, *Melicytus ramiflorus*, *Leptospermum scoparium*, *Metrosideros lucida*, *Griselinia littoralis*, *Pseudopanax crassifolium*, *Dracophyllum longifolium*, *Rapanea Urvillei* and *R. salicina*[2]).

1) Probably this should not be considered coastal.

2) These are not all present in any one locality.

b. Pohutukawa (Metrosideros tomentosa) grove.

In the Northern botanical province, groves or girdles of *Metrosideros tomentosa* (Plate XIV, Fig. 19), at times adorn the shore just above high-water mark. Such trees have only short primary trunks from which spring numerous ascending branches, which, copiously branching, form dense heads covered with wind-resisting, thick, green leaves, white beneath with dense tomentum. Frequently, the association may be pure, but at other times certain of the coastal trees may be present.

c. Northern coastal-forest.

Though more uniform than is coastal-forest further to the S., since, with two exceptions, the N. possesses all the littoral trees, the composition of this association varies so considerably, that only a quite general account can be given.

The forest is less tall, the tree-trunks more slender and the under-growth more open than in rain-forest generally. Where wind-swept, the roof is close, but, as the forest depends on shelter, the wind-effect is not strongly marked. *Metrosideros tomentosa* is generally dominant, but *Corynocarpus* is often a most important member and will give a distinct facies. *Leptospermum scoparium* may dominate a sub-association, as in gully-forest surrounded by heath. The commonest of the remaining coastal trees are, — *Macropiper*, *Pittosporum crassifolium*, *Dodonaea viscosa* and *Pseudopanax Lessonii.* Common non-coastal trees are: — *Knightia*, *Beilschmiedia tarari* (in some parts), *Dysoxylum*, *Hoheria populnea* (in the far N.), *Melicytus ramiflorus*, *Rapanea Urvillei* and *Vitex lucens*. Tree-ferns (*Cyathea dealbata*, *C. medullaris*) are abundant. *Freycinetia Banksii* (also as a liane), *Paratrophis microphylla*, *Melicope ternata* (also a tree), *Styphelia fasciculata*, *Geniostoma*, *Rhabdothamnus Solandri*, various species of *Coprosma* and *Brachyglottis repanda* may form the undergrowth. Many of the smaller ferns will be present, especially, — *Adiantum hispidulum*, *Pteris comans*, *P. macilenta*, *P. tremula*, *Blechnum filiforme* (liane), *Doodia media*, *Asplenium bulbiferum*, *A. lucidum*, *Polystichum Richardii*, *Dryopteris pennigera*, *D. velutina*, *Polypodium diversifolium*, *P. tenellum* (on rocks), *Cyclophorus serpens.* Near streams, there may be in the far N. the fine, large- but thin-leaved herb *Colensoa physaloides.*

Certain local associations, as also the distribution of the rarer species, demand attention. On the more or less sheltered slope of the West King (Three Kings' Islands), the forest contains the remarkable araliad, *Meryta Sinclairii*, as the principal tree. This attains a maximum height of 7.5 m; the trunk, 15—45 cm in diam, branches into a rounded crown covered with the great, oblong, bright-green, shining coriaceous leaves, the blade 50 cm long. A luxuriant form of *Cordyline australis* together with *Macropiper excelsum* var. *major* and tall *Pteris comans*, according to CHEESEMAN, adds to the tropical aspect of the forest (1891: 412). *Coprosma macrocarpa* and *Paratrophis Smithii.*

both peculiar to the group, are also present. *Meryta* is also abundant on the East King, but has not been found on the Great King, which is by far the largest island of the group.

On the Poor Knights' Islands, the tree- and shrub-association of a sheltered gully consists of: — luxuriant *Cordyline australis* (very abundant), *Macropiper excelsum* var. *major*, *Entelea*, *Hymenanthera novae-zelandiae*, *Melicytus ramiflorus*, *Suttonia divaricata*[1] (an unexpected shrub), *Sideroxylon*, *Geniostoma*, *Veronica Bollonsii* and *Myoporum laetum*.

Coming now to some of the rarer coastal trees, — *Pittosporum Huttonianum* occurs only on the Great and Little Barrier Islands and Cape Colville Peninsula; *P. ellipticum* at Mount Manaia and the coast to the immediate north of Manakau Harbour; *P. Fairchildii* is confined to the Three Kings; *Olea apetala* occurs on a few of the outlying islands, and at Whangarei Heads, and *Meryta*[2]) on the Hen and Chickens, in addition to the Three Kings.

d. Karaka (Corynocarpus) forest.

This association occurs at various places from Wellington to Cheviot in the South Island, but, in proceeding S., its species greatly decrease. *Corynocarpus* has already been cited as an important member of northern coastal-forest, but it and its associates have been considered at best a sub-association.

A typical example, such as occurs on the Wellington coast, or Kapiti Island, has a somewhat billowy, close roof, the different greens of which denote certain species as, — dark-green, *Corynocarpus*; pale yellowish-green, *Melicytus ramiflorus*; bright pale-green, *Myoporum*; darkish-grey, *Leptospermum scoparium*. An outer girdle faces the shore, composed of: — *Macropiper*, *Paratrophis opaca*, *Urtica ferox*, *Hedycarya arborea*, *Corynocarpus*, *Melicytus ramiflorus*, *Pseudopanax crassifolium*, *Myoporum*, *Coprosma Baueri*, and of these the two last and the *Urtica* are nearest the shore. A little further from the sea, other trees are present, especially: — *Rhopalostylis sapida*, *Knightia*, *Pittosporum tenuifolium*, *Melicope ternata*, *Dysoxylum spectabile*, *Pennantia*, *Fuchsia excorticata*, *Nothopanax arboreum*, *Coprosma grandifolia*, *Brachyglottis repanda* and *Olearia Cunninghamii*. The principal lianes are *Blechnum filiforme* and *Freycinetia* (both important floor-plants also). Frequently, the interior of the forest is open. Ferns are common, e. g. — *Adiantum affine*, *A. fulvum*, species of *Pteris*, *Dryopteris velutina*, *Polystichum Richardii* and *Asplenium Hookerianum*.

In the South Island *Corynocarpus* extends to Banks Peninsula and the community is of frequent occurrence from the R. Clarence to Cheviot. But the above association is dominated by *Myoporum* which at times is virtually pure. The other trees, any of which may be absent, are: — *Macropiper*, *Melicope ternata*, *Dodonaea*, *Corynocarpus*, *Fuchsia excorticata*, *Nothopanax arboreum*, *Rapanea Urvillei*, *Alectryon excelsum*, *Pittosporum tenuifolium*, *Carpodetus*

1) This has leaves much larger and thinner than I have seen elsewhere.

2) Its occurrence on the Poor Knights' Islands seems doubtful.

serratus, *Sophora microphylla*, *Griselinia littoralis*, *Aristotelia racemosa*. At times the shrubby *Urtica ferox* is common.

e. Southern coastal forest.

Throughout much of Southern botanical province the forest near the sea is merely the ordinary lowland tree-association of the neighbourhood, but, in exposed positions, with certain wind- and spray-resisting members more abundant. *Macropiper* is still extremely plentiful on Banks Peninsula; *Myoporum*, in many places, dominates the shore-forest of the South Otago district; along the whole E. coast where forest can exist, *Melicytus ramiflorus* is an important gregarious tree.

On the flat ground above the cliffs to the S. of Westport, the forest is wind-shorn *Nothofagus*-taxad with stunted, dense *N. Solanderi* dominant. Other important constituents are: — *Phyllocladus alpinus*, *N. fusca*, *Weinmannia racemosa*, *Metrosideros robusta* and *Dracophyllum longifolium*. The principal lianes are, — *Freycinetia* and *Metrosideros scandens*.

Along the coast of the northern part of the Western district, there is a narrow strip of strongly wind-shorn forest. This, between Greymouth and Hokitika, consists of stunted taxad-forest with *Podocarpus dacrydioides* and *Dacrydium cupressinum*, 6—9 m high, dominant and the branches of the first-named are much more widely-extended than usual, also *Carpodetus*, *Weinmannia racemosa*, *Aristotelia racemosa*, *Fuchsia excorticata*, *Rapanea salicina*, *Coprosma lucida*, *C. foetidissima*, *C. areolata*. *Griselinia lucida* and *Astelia Cunninghamii* are common epiphytes. *Metrosideros scandens* and *Rubus australis* are the principal climbers.

In the southern part of the Western district, where the shingle-beach slopes upwards to the land, as near the mouth of the Paringa and at Bruce Bay, a girdle of trees stands in front of the taxad-forest, which itself bears not the slightest evidence of its proximity to a wind-swept coast. The association consists of: — *Cordyline australis*, *Hedycarya arborea*, *Sophora microphylla*, *Coriaria ruscifolia*, *Weinmannia racemosa*, *Plagianthus betulinus*, *Melicytus ramiflorus*, *Leptospermum scoparium*, *Metrosideros lucida*, *Fuchsia excorticata*, *Griselinia littoralis*, *Rapanea Urvillei* and *Coprosma propinqua*.

In the Stewart, Fiord and southern part of the South-Otago districts, *Metrosideros lucida* is the dominant coastal-forest tree, thanks to its extreme plasticity with regard to wind and subantarctic conditions in general.

Section II.

The Vegetation of the Lowlands and Lower Hills, (Sea-level to 600 m altitude or nearly 900 m in the north).

Chapter I. General Observations on the Vegetation of the Lowlands and Lower Hills.

1. General.

The portion of New Zealand treated of in this section varies considerably in altitude in proceeding from N. to S. In the Northern botanical province, with the exception of one or two summits of the Thames Mountains, all the hills, even when they considerably exceed 600 m altitude, bear a vegetation of a lowland stamp and true alpine plants are wanting. All the same, certain species ascend far higher than others and there are more or less distinct altitudinal belts. In the Central province, especially in the N., high-mountain species do not generally appear until an altitude of at least 800 m is reached. In the Southern Province, though 600 m may be taken as the upper average limit of the lowland-lower mountain belt, no universal delimiting line can be fixed. Where, as in the W. and S., the climate is wet and cloudy days abundant, should the edaphic conditions be favourable, quite a number of species, otherwise typically alpine or subalpine, descend to sea-level even so far N. as lat. 42° S. In Stewart Island, not species merely, but actual subalpine associations, occur at virtually sea-level. Furthermore, the foot-hills, bases of the high mountains and the valleys of the South Island, at an altitude of considerably less than 600 m, frequently possess a vegetation subalpine rather than lowland.

The area under consideration comprises the North Island as a whole, excepting the actual coast-line, one or two mountain summits in the Thames subdistrict and the higher portions of the high mountains at above an altitude of 800 m at the very least. In the South Island the lowland-lower mountain belt is much more restricted, its greater part follows the coast-line, though it passes inland by way of the lower slopes of the mountains and the numerous valleys, so that, in places, there is lowland vegetation close to the foot of the actual Divide. In Stewart Island the line of demarcation may be put down at about 450 m, though it is considerably less in the S.

Notwithstanding the extensive plains in both the main Islands, much of the land-surface is extremely broken and hilly, while in many places deep gorges are a characteristic feature, so that there is great diversity of habitats throughout. The summit-vegetation of comparatively low hills, if isolated or specially exposed. bears a mountain stamp both in species and physiognomy.

Much lowland vegetation has been not merely modified in the course of settlement but actually wiped from the face of the land. But, except in a few instances, there are sufficient indications to show clearly enough of what the primitive plant-covering consisted, so that it is still possible to give a fairly accurate sketch of primeval lowland New Zealand. Many areas too remain absolutely in their virgin condition and this is the case with regard to forest in general and to the greater part of the South Island W. of the Southern Alps as also to almost the whole of Stewart Island.

2. Floristic details.

The lowland-lower-mountain flora consists of the following elements: 1. Species confined to the lowland-lower-mountain belt, here spoken of as "lowland". 2. Species found both in the lowlands and high mountains. 3. Species truly alpine or subalpine but which occasionally occur in the lowlands. 4. Coastal species which extend inland for some distance, or which occur far from the sea under special circumstances. The total number of species belonging to these 4 classes is 998 made up of 517 belonging to the first class, 348 to the second, 91 to the third and 42 to the fourth. Leaving out of consideration the coastal and purely high mountain elements, since they are of extremely slight importance in the general vegetation, the number of species is 865 which belong to 98 families and 324 genera.

Considering first of all the 517 purely lowland species, they belong to 81 families and 226 genera; and 327 (63 p. c.) are endemic, 130 (25 p. c.) Australian (91 pteridophytes and monocotyledons), and 13 temperate South American. With regard to their distribution in New Zealand, 249 (48 p. c.) occur in all the botanical provinces but only 102 of these extend to Stewart Island; 72, 24 and 54 species are peculiar to the Northern, Central and Southern provinces respectively, the total number of species in each province in the order named being, — 407, 388 and 336; 84 species are confined to the Northern and Central provinces; 31 to the Central and Southern and 2 to the Northern and Southern.

Change of altitude brings about considerable alteration in the flora, 146 species not ascending above 300 m altitude, 212 not above 600 m and 159 not above 900 m. The 146 species of the lowest altitudinal belt are, with but few exceptions, of restricted distribution, more than 40 p. c. having been observed so far in but one or two localities; indeed, with the exception of perhaps some 30 species, many of which are far from widespread, their absence from the vegetation would be hardly noticed.

The following 15 families and 94 genera are confined to the lowlands and lower hills: — (Families) *Salviniaceae*, *Pandanaceae*, *Sparganiaceae*, *Palmae*, *Lemnaceae*, *Amaryllidaceae*, *Lauraceae*, *Monimiaceae*, *Rutaceae*, *Meliaceae*, *Icacinaceae*, *Elatinaceae*, *Passifloraceae*, *Oleaceae*, *Gesneriaceae*: (Genera) *Loxsoma** [1]),

1) An asterisk here denotes that the genus is confined to New Zealand.

Hemitelia, *Cyathea*, *Leptolepia*, *Lindsaya*, *Adiantum*, *Cheilanthes*, *Pellaea*, *Paesia*, *Doodia*, *Nephrolepis*, *Cyclophorus*, *Notochlaena*, *Lygodium*, *Todaea*, *Marattia* (Filices); *Azolla* (Salviniac.); *Phylloglossum* (Lycopod.); *Agathis* (Pinac.); *Freycinetia* (Pandanac.); *Sparganium* (Sparganiac.); *Paspalum*, *Isachne*, *Alopecurus*, *Simplicia**, *Amphibromus*, *Arundo*, (Gramin.); *Mariscus*, *Fimbristylis*, *Lepidosperma* (Cyperac.); *Rhopalostylis* (Palmae); *Dianella* (Liliac.); *Hypoxis* (Amaryll.); *Bagnisia* (Burmanniac.); *Dendrobium*, *Bulbophyllum*, *Earina*, *Sarcochilus*, *Spiranthes*, *Orthoceras*, *Caleana*, *Acianthus*, *Calochilus*, *Townsonia*, *Corysanthes* (Orchid.); *Peperomia* (Piperac.); *Ascarina* (Chloranthac.); *Elatostema*, *Parietaria*, *Australina* (Urticac.); *Loranthus*, *Phrygilanthus* (Loranthac.); *Fusanus* (Santalac.); *Polygonum* (Polygonac.); *Alternanthera* (Amarantac.); *Myosurus* (Ranun.); *Hedycarya*, *Laurelia* (Monimiac.); *Beilschmiedia*, *Litsaea*, *Cassytha* (Laurac.); *Ixerba** (Saxifrag.); *Ackama** (Cunoniac.); *Chordospartium**, *Nothospartium** (Legum.); *Pelargonium* (Geran.); *Phebalium*, *Melicope* (Rutac.); *Dysoxylum* (Meliac.); *Pennantia* (Icacinac.); *Hoheria** (Malvac.); *Elatine* (Elatinac.); *Melicytus* (Violac.); *Tetrapathaea** (Passiflor.); *Eugenia* (Myrtac.); *Schefflera* (Araliac.); *Daucus* (Umbell.); *Olea* (Oleac.); *Geniostoma* (Loganiac.); *Sebaea* (Gentian.); *Cuscuta* [1]) (Convolvulac.); *Tetrachondra* (Borraginac.); *Vitex*, *Teucridium**, (Verbenac.); *Scutellaria* (Labiatae); *Jovellana* (Scroph.); *Rhabdothamnus** (Gesneriac.); *Galium* (Rubiac.); *Colensoa** (Campan.); *Siegesbeckia*, *Bidens*, *Centipeda*, *Brachyglottis**, *Picris* (Compos.);

The principal families of the special lowland flora with the number of species in each are: — *Filices*, 84; *Cyperaceae*, 46; *Orchidaceae*, 43; *Compositae*, 41; *Rubiaceae*, 19; *Leguminosae*, 17; *Gramineae* and *Scrophulariaceae*, 16; *Myrtaceae*, 13; *Ranunculaceae*, 11; *Umbelliferae*, 10; *Onagraceae*, 9; *Taxaceae*, *Liliaceae*, *Pittosporaceae* and *Araliaceae*, 8. The principal genera and the number of species in each are: — *Coprosma*, 13; *Carex* and *Carmichaelia*, 11; *Veronica* and *Olearia*, 10; *Hymenophyllum* and *Scirpus*, 9; *Cladium*, *Thelymitra*, *Pittosporum* and *Epilobium*, 8; *Blechnum*, *Asplenium*, *Corysanthes*, *Metrosideros* and *Hydrocotyle*, 7.

The 348 species of pteridophytes and spermophytes common to the lowland and high mountain floras may be roughly divided into the three classes of those more or less abundant in both areas (158 species), those more frequently lowland species (99) and those more frequently high mountain species (91). These figures however might give the impression that the lowland-high mountain species belong equally to the two floras, a view that would be erroneous. To begin with, 174 species (50 p. c.) are absent in the Northern botanical province, if the Thames sub-district be excluded. Moreover only 73 species (20 p. c.) can be considered as true members of the high mountain flora, while but 54 species (15 p. c.) ascend higher than 1200 m and, on the other hand, 85 species

1) Perhaps not indigenous; the species *C. densiflora* Hook. f. is probably identical with *C. racemosa* Mart. which could easily have been introduced into New Zealand with lucerne seed. Neither CHEESEMAN nor I have seen specimens of *C. densiflora* which was originally collected at Port Underwood, Marlborough by LYALL.

do not reach an altitude of 900 m. The greater part of the 348 species belong either to that portion of the steppe area where lowland and high mountain species mingle or to the montane and subalpine forest, the members of which are exposed to conditions materially different from those of an open subalpine or alpine hillside. Further, many plants of lowland lakes, swamps and bogs find conditions not very different to what they are accustomed in the allied habitats up to about 900 m altitude. So, too, the conditions offered by rocks and river-beds from sea-level to 600, or even 900 m altitude in some localities, are not very different.

Some species occur so abundantly both in certain lowland, or coastal, and high mountain formations as to be of great physiognomic importance, especially, — *Polystichum vestitum*; *Danthonia Raoulii*, *Poa caespitosa*, *Festuca novae-zealandiae*; *Hypolaena lateriflora*; *Phormium Cookianum*; *Nothofagus Menziesii*; *Weinmannia racemosa*; *Discaria toumatou*; *Leptospermum scoparium*, *Metrosideros lucida*; *Dracophyllum longifolium*; *Suttonia divaricata*; *Veronica salicifolia*, *V. Hulkeana*; *Coprosma foetidissima*; *Olearia insignis*, *Raoulia australis*, *R. lutescens*, *R. tenuicaulis*, *Cassinia Vauvilliersii*. Although the same species may be present alike in the subalpine, alpine and lowland belts yet under the local environments the growth-form may be altogether different as in the case of *Leptospermum scoparium* as a low tree in a lowland forest and a prostrate, rooting mat on a subalpine moor, or *Weinmannia racemosa* a tall, massive tree in the lowlands and a dense shrub in the subalpine scrub.

The ecological conditions of the lowland-lower mountain belt are so dissimilar in different parts of the area that no general account can be given here. The effect of change in latitude, or of excessive rainfall in certain localities, has already been alluded to in regard to the coastal vegetation and the same remarks hold equally with regard to the lowlands and lower hills.

Chapter II.

The leading Physiognomic Plants and their Growth-forms.

1. Forest Plants.

a. The Taxaceae.

The various species of *Taxaceae* play a most important part in the physiognomy of much of the rain-forest. *Dacrydium cupressinum* (rimu, red pine) is the most important physiognomically while *Podocarpus dacrydioides* (kahikatea, white pine) comes next. Very noticeable too are *P. totara* (totara), *P. ferrugineus* (miro) and *P. spicatus* (matai, black pine), the two latter, when adult, being physiognomically identical.

All the above are tall straight trees with long, frequently massive trunks unbranched for their lower two-thirds or more, sometimes buttressed bases, far-spreading lateral roots, which often rise high above the ground-surface, and, usually, small heads of foliage.

P. ferrugineus, *P. spicatus* and *P. totara* somewhat resemble gigantic yew trees, especially the two former. Their leaves are linear, those of *P. ferrugineus* and *P. spicatus* are green and distichous, but those of *P. totara* yellowish-green, coriaceous and spirally arranged. *P. dacrydioides* has the cupressoid leaf-form, the small subulate lanceolate acuminate leaves closely imbricating and tightly pressed to the shoot-axis. The markedly-different juvenile plant has flat linear-falcate leaves of a reddish or bronze colour inserted on the flanks of the twigs. The crown of the adult is extremely small and out of all proportion to the size of the tree. (Plate XXVII, Fig. 34.)

Dacrydium cupressinum stands out clearly from all the above. Its ultimate branchlets are close together and pendulous giving a "weeping" habit which with the yellowish hue of the leaves makes the tree unmistakeable, even at some distance. The leaves are linear, acute and pressed to the stem. (Plate XV, Fig. 20.)

The flowers of the *Taxaceae* are nearly always dioecious. The staminate cones are catkin-like, and pollen is abundant. The mature pistillate cones consist in *P. totara*, *P. dacrydioides* and *D. cupressinum* of a nut seated on a fleshy red receptacle, which, in the case of *P. dacrydioides*, gives a bright and striking colour to the crown of the tree in the autumn. *P. spicatus* and *P. ferrugineus* bear succulent plum-like drupes, those of the former being globose, black and 7 mm in diameter and those of the latter reddish-purple and covered with a waxy "bloom". All these fruits are eaten by pigeons, but usually the seeds are not conveyed to any distance, for the birds remain near the food-supply until it is exhausted.

b. Agathis australis Salisb. (*Pinac.*) Kauri.

The Kauri is a very tall, massive forest-tree, some 24—30 m high, or higher. It has a straight columnar trunk 1—4 m in diam.[1]) unbranched for 15—21 m or more and remarkably uniform in thickness for that distance. The bark is thick, shining grey in colour and constantly being shed in large flakes leaving ripple-like marks and reddish warts on the newly-exposed bark. At about its upper third or fourth the tree gives off great branches at an angle of 45° or less. These finally bear somewhat twisted gnarled terete branchlets marked with old leaf-scars. Smaller branchlets are given off at a right angle, and these generally branch once more into still shorter but leafy members. The arching of the ultimate branch-system brings the leaves into such close proximity that

1) Trees of much greater dimensions are not uncommon. CHEESEMAN (1906, p. 645) cites 45 m as the extreme height, while a diameter of about 6,5 m has been recorded. Trees of abnormal girth have usually short and hollow trunks.

a close head of olive-green foliage results. The leaves are closely inserted in a spiral; they imbricate but do not touch. They are dark-green, thick, coriaceous, rather stiff, linear-oblong to ovate-oblong and about 3.7 cm long by 1.2 cm broad.

The flowers are monoecious. The staminate cones produced in September and early October are cylindrical and about 3 cm long. The ovulate when ripe are almost spherical, hard, dark-green and from 5—7 cm in diam. The scales are rather thin, each bears one compressed and winged seed. When mature, in March (more than a year after pollination) the scales fall away from the woody axis of the cone, and the seeds drop to the ground, or, were a high wind blowing, might be carried a short distance. Quite young trees may bear cones.

Young trees differ much in appearance from adults. The branches are slender and inserted at a right angle to the trunk; they arch upwards at their extremities whence are given off short yellowish-green branchlets closely covered near their extremities with leaves. Such trees are densely leafy and pyramidal in form, tapering gradually to a rather blunt apex. Juvenile leaves are longer and narrower than adult. The rootlets of the Kauri are furnished with nodules.

Agathis australis is endemic and does not occur to the S. of lat. 38° S. It is of very slow growth and attains a great age [1]) but probably the high estimate of T. KIRK as below is far too great.

c. *Metrosideros robusta A. Cunn.* (*Myrtac.*), *Rata and M. lucida* (*Forst. f.*) *A. Rich.*, *Southern-rata*, *Ironwood.* (Plate XVI, Fig. 21.)

Both the above trees are of irregular growth. Their leaves are more or less elliptic-lanceolate in shape, 4 cm, or so, long, glossy green, coriaceous and dotted beneath with numerous oil-glands. The bark is reddish-brown and peels off in large strips which frequently hang from the trunk. The branches are long, spreading and generally irregular in form. They finally give off many leafy twigs which touch and make dense masses of foliage, but that of one branch-system is held distinct from those adjacent and not intermingling.

Both species though "normally" forest-trees, (and *M. robusta* may be of gigantic proportions), may remain bushy shrubs and bloom freely.

Besides their massive irregular trunks, their profusion of crimson flowers renders both species specially conspicuous.

M. robusta nearly always, and *M. lucida* not infrequently, commence their career as epiphytes and in such cases their trunks are really a collection of intergrowing roots, the host tree's trunk, strangled to death, having decayed. It

1) According to a computation from the annual rings T. STEWART (1905, p. 376) found an average growth of 30 cm yearly during 42 years. A section of a Kauri log in the Auckland museum 2.4 m in diam. shows 455 rings, and the percentage of sap-wood indicates that the tree was in its prime. T. KIRK assumes slower development and estimates the age of a tree 2 m in diam. as 1260 years, and one celebrated specimen at Mercury Bay at more than 4000 years (KIRK 1889, p. 145). — Compare CHEESEMAN in Transact. New Zeal. Inst. XLVI (1914) 9—19.

is quite common therefor to be one or more holes extending right through the rata's trunk or there may be an archway through the broad base.

M. robusta is confined to the lowland and montane belts of the Northern and Central botanical provinces except for a brief western extension into the Southern province. *M. lucida* is montane only in the Northern province nor does it extend to the N. of Whangarei and the Little Barrier. In the S. it occurs from sea-level to the subalpine belt but chiefly where the rainfall is high.

d. The two species of Weinmannia.

The tropical genus *Weinmannia* (Cunoniac.) is represented in New Zealand by the closely-related endemic species, *W. sylvicola* (Tawhero) and *W. racemosa* (Towai, Kamahi), the former being almost confined to the Northern and the latter occurring chiefly in the Central and Southern botanical provinces, though extending into the Northern to the S. of the Auckland Isthmus.

Both trees are much alike. Their trunks are frequently irregular in form, especially those of *W. racemosa*. These, near the base, are not infrequently composed of roots grown together through the young trees having in the first instance grown upon stems of tree-ferns or fallen tree-trunks (Plate XVII, Fig. 22). The branches form a compact, moderately-spreading crown. The bark is even, pale-coloured, thin and full of tannin. The adult leaves are somewhat thick, coriaceous, dull- or yellowish-green. The juvenile are compound in both species, those of *W. sylvicola* being pinnate but those of *W. racemosa* either pinnate or ternate, whereas in the adult the leaves of the former are usually trifoliate though sometimes pinnate, but those of the latter are invariably simple.[1])

The flowers are small, white or pinkish-white and arranged in terminal racemes about 8 cm long which are produced in such profusion that a tree in full bloom of either species is a charming spectacle.

e. The two species of Beilschmiedia (Laurac.)

1. B. tawa (A. Cunn.) Benth. and Hook f. (Tawa).

The tawa is an evergreen forest-tree, 12—24 m high, which gives a mark to the forests of the Northern and Central botanical provinces, especially, when as a young tree, it forms a considerable portion of the undergrowth. Its trunk, 30 cm—1.2 m in diam. is covered with a smooth, blackish bark. The branches are slender and finally bear willow-like, thin leaves 7—8 cm long, yellowish-green in colour on the upper surface and beneath glaucous with a waxy covering. The flowers are hermaphrodite, minute, greenish-yellow and arranged in slender panicles 5—7 cm long. The fruit resembles a small damson plum; it is dark-purple and about 2.5 cm long.

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1) When the slight differences between the two species, both in leaf and flower, are considered it is probable that *W. sylvicola*, though now "fixed" is really a flowering juvenile form of *W. racemosa*, and this view is supported by the facts that it frequently blooms when a mere shrub, while the adult *W. racemosa* frequently puts forth reversion-shoots bearing compound leaves.

Young trees 2.4—3 m high possess a slender, erect, dark-coloured main-stem from which pass off rather short and distant very slender branches from which hang the pale-green thin leaves, whitish on their under-surfaces and not crowded together. Such young plants are extremely graceful and when they occur in abundance lend a special charm to the forest.

2. B. tarairi (A. Cunn.) Benth. and Hook f. (Taraire).

The taraire is a handsome evergreen tree 15—24 m high with a straight erect, often slender trunk 45—90 cm in diam. covered with brown or reddish-brown bark with many longitudinal cracks but which, at a distance, frequently appears white through the abundance of a crustaceous lichen. The branches are few and short; the lower pass off at a right angle and frequently droop or arch somewhat; the upper are fixed at a narrower angle. Finally, short branches pass off at an acute angle; these are quite stout, furnished closely with leaves, and so form a small dense crown. The leaves are obovate to broadly oblong, about 12.5 cm long by 7.5 cm broad, entire, dark-green, slightly glossy, coriaceous, stiff but elastic, the distant pale-yellowish raised veins giving special firmness; the under-surface is bluish-white owing to a covering of wax.

The flowers are hermaphrodite, extremely small, white and arranged in axillary panicles with stout branches and shorter than the leaves. The fruits are rather larger than those of *B. tawa*.

B. tarairi is confined to the Northern botanical province, but is rare or local to the south of the Auckland Isthmus.

The two species of *Beilschmiedia* are endemic and with the Australian *B. obtusifolia* constitute the subgenus *Nesodaphne*.

f. Various small trees found in many forests of the main islands.

The following often form part of the second tier of tree-tops beneath the main roof. At times, they may form much of the vegetation, or be a feature of the landscape when the tall trees have been removed by man.

1. Carpodetus serratus Forst. (Saxifragac.) Putaputawheta, New Zealand hawthorn.

C. serratus with a maximum height of about 9 m, a trunk 15—22 cm in diam., has a close head of flattened spreading branches. The leaves are ovate-oblong, serrate, 2—4 cm long, rather thin, but they are specially noticeable through their yellowish variegation caused by the dark-green colouring above the veins of the upper surface and the yellowish green spaces between[1]).

1) The juvenile form has a denser habit, with the stems twiggy and entangled. The leaves are half as long than those of the adult, or less; the staining above the veins darker green but the interspaces yellower; the under surface is stained purple or pink; the teeth are much sharper and the leaf in general more hairy. This shrubby juvenile form persists for a number of years.

The flowers are hermaphrodite, white, arranged in broad panicles shorter than the leaves. Produced in profusion, they render the tree a striking object during summer. The capsule is globose, about the size of a small pea, and when ripe, black and shining; it remains on the tree for about a year, and flowers and fruit may be present at the same time.

The genus is monotypic and endemic.

2. Pittosporum tenuifolium (Pittosporac.) Kohuhu, Powhiwhi.

P. tenuifolium is a small tree 4.5—9 m high with a slender trunk rarely more than 30 cm in diam. covered with dark-coloured bark and having a rounded head of thin branches and twigs bearing numerous more or less oblong green leaves 2.5—6 cm long, but which vary much in shape and size in different individuals.

The flowers are hermaphrodite, axillary, about 1 cm long, solitary or occasionally fascicled, chocolate-coloured, and are succeeded by woody, ovate capsules 1.5 cm long, which finally open by three valves, exposing the black seeds embedded in a transparent glutinous substance.

3. Pittosporum eugenioides A. Cunn. (Pittosporac.) Tarata, Lemonwood, Turpentine tree.

P. eugenioides is an exceedingly handsome evergreen tree, 6—8 m high, having a close round head of slender branches and dark-coloured branchlets bearing extremely glossy, bright-green, elliptical, subcoriaceous leaves, 5—10 cm long. The flowers are more or less dioecious, yellow, sweet-scented and arranged in compound umbels, which are conspicuous when in full bloom. The fruits are small, similar to those of the genus in general, and require about a year to attain maturity.

The species is wanting in Stewart Island, and rare or absent over wide areas in the W. of the South Island.

4. Aristotelia racemosa (A. Cunn.) Hook. f. (Elaeocarpac.), Makomako, Wineberry.

The wineberry is an evergreen to almost deciduous shrub or small tree 1.8—7.5 m high with a trunk, in large examples, 30 cm in diam. The branches are slender and spreading. The bark is thin, red on young but black on older parts. The leaves are ovate, often cordate at the base, serrate, thin, bright- to dark-green above and frequently reddish beneath, about 8 cm long, but in moist districts attaining, even in the open, a length of 20 cm and a breadth of 13.7 cm.

The flowers are dioecious, small, rose-coloured, sweet-scented and arranged in much-branched, slender panicles. The berries, produced in abundance, are red or black.

The plant is of physiognomic importance merely because, after forest is burned, it may become dominant. It occurs from sea-level to 900 m altitude.

5. Melicytus ramiflorus Forst. (Violac.) Mahoe, Cowleaf, Whiky-wood.

M. ramiflorus is an evergreen small tree or shrub attaining a maximum height of 9 m with a trunk 30—60 cm in diam. covered with thin palish-grey bark. The crown is rounded, dense and made up of slender boughs and numerous brittle twigs. The leaves are oblong-lanceolate, 5—12 cm long, rather thin, green or yellowish-green and bluntly serrate. The small dioecious flowers are born in fascicles on the naked branches below the leaves. The berries are about 5 mm in diam., but their great number, violet colour and position render them conspicuous.

The species occurs in Norfolk Island and Tonga as well as New Zealand.

6. Fuchsia excorticata (Forst.) Linn. f. (Onagrac.) Kotukutuku, New Zealand fuchsia.

F. excorticata is a deciduous or semi-deciduous tree or shrub with an extreme height of 12 m. The trunk is stout, sometimes 90 cm in diam. though generally much less, most irregular in shape and often semi-prostrate. The bark is thin, smooth and long papery strips hang from the trunk, leaving a shining green surface beneath. The leaves are ovate-lanceolate to lanceolate, 5—10 cm long, thin, soft, green above and silvery beneath. The solitary flowers, 3 cm long, are bright-green blotched with purple. They appear in spring before the leaves and depend from the leaf-axils. The berries are 1.2 m long, black and juicy; they are much relished by birds.

The species is endemic; it occurs from sea-level to about 900 m altitude.

7. Nothopanax arboreum (Forst. f.) Seem. (Araliac.) Whauwhaupaku, Ivy-tree.

N. arboreum is a small evergreen tree, 7 m high at most, with a slender trunk and numerous branches forming a dense rounded head. The leaves are digitately 7—5-foliate with stout flexible petioles 12 cm or more long which have a broad sheathing base that protects the young bud; the leaflets are more or less oblong, 7.5—17 cm long, rather dark-green, shining, coriaceous but not stiff. The flowers are dioecious, small, and arranged in compound terminal umbels. The fruit is broader than long, 6 mm in diam., black and so abundant as to be conspicuous.

The juvenile form remains for a considerable time unbranched with a stout, erect, bamboo-like, terete stem marked below with grey leaf-scars and bearing the distant leaves above, the blades held horizontally on the long petioles.

The species is endemic; it ascends to 600 m.

8. Rapanea Urvillei (A. DC.) Mez (Myrsinac.) Mapou, Tipou, Red maple.

R. Urvillei is a small evergreen tree or shrub 3—6 m high with a slender trunk 30 cm more or less in diam. covered with thin dark-coloured bark, which however is reddish on the twigs. In general appearance the tree much resembles *Pittosporum tenuifolium*, already described, but the leaves are crinkled and their general tint is reddish-brown. They are more or less oblong, 2.5—5 cm long, dotted with round pellucid glands and have strongly undulate margins. The flowers are dioecious, very small and crowded in fascicles on the naked stems below the leaves. The fruit is small, globose and black.

The species is endemic and occurs from sea-level to an altitude of about 900 m.

g. The species of Coprosma.

The genus *Coprosma* plays an important part in the physiognomy of the vegetation throughout almost the whole New Zealand botanical region at nearly all altitudes and in all classes of formations from indeed those of rock to swamp. It may therefore be guessed that the species will exhibit much epharmonic variation, although this cannot, at the present time, be always associated with the environment of the species, but is to be traced rather to former climatic or edaphic conditions. Considering now only the lowland and montane species, and putting aside the turf-forming class, there are two principal ecological categories[1]), viz — 1. Tall shrubs, or low trees, of an upright habit with fair-sized leaves, and 2. Smaller shrubs of dense growth made up of many interlacing twiggy branches bearing small leaves. To the former belong: — *C. grandifolia*, *C. lucida*, *C. robusta*, *C. arborea*, *C. tenuifolia*, *C. Cunninghamii* and *C. foetidissima* and to the latter the extreme divaricating forms such as *C. rhamnoides*, and even those taller and more open, as that most common plant of forest undergrowth, *C. rotundifolia.*

The flowers of all the species are dioecious, small, rather inconspicuous but produced in abundance and are specially adapted for wind-pollination. Sometime the calyx is wanting, its place being supplied by connate bracts which closely resemble a calyx. The drupes, containing two plano-convex pyrenes, are generally most abundant, and, when transparent or brightly coloured render the shrub both beautiful and conspicuous.

h. Rhopalostylis sapida (Sol.) Wendl. and Drude (Palmae), Nikau, Nikau palm.

The nikau is a tuft-tree 1.8—7.5 m high with a smooth, greenish, slender trunk 14—22 cm in diam. marked with pale-coloured rings of old leaf-scars at distances apart of about 2.5 cm and bearing near its apex a crown of large pinnate leaves 1.2—2.4 m long, which radiate outwards and upwards at a variable angle. The leaves are a moderately dark shining green, the midrib is very thick and also green, but its secondary branches are yellow. The leaf-bases form a cup which frequently gets filled with dead leaves &c. to a depth of 30 cm, or more. Adventitious roots of a red colour pass off from near the base of the trunk at a distance of 30 cm from the ground. If the

1) There is also the class of low; sparsely-branched twiggy shrubs e. g. — *C. Colensoi*, *C. Banksii.*

terminal bud is destroyed the stem may branch (CHEESEMAN 1907: 448), and several branching examples have been recorded and figured.

The inflorescence is situated at the bases of the leaves and consists of a much and densely branched spadix enclosed within two boat-shaped bracts. The flowers are monoecious. The drupes are 12.5 mm long and bright red.

R. sapida is endemic and almost confined to the Northern and Central botanical provinces, but it extends on the E. to Banks Peninsula and on the W. to the base of the Paparoa Mountains.

i. The woody lianes.

Woody lianes strongly accentuate the tropical appearance of the New Zealand rain-forest. In many places their "ropes" hang swinging from the tree-tops, solitary or intertwined. Those of *Rubus australis* (Rosac.), *Rhipogonum scandens* (Liliac.) and of *Muehlenbeckia australis* (Polygonac.) are of prime physiognomic importance, the first-named covered with rough, brown bark and, at times, 8 cm in diam., and the second smooth, black and jointed. High in the tree-tops their leaves are of no physiognomic moment, but on an open hillside, the *Rubus* forms rounded masses of interlaced slender, leafy stems, while in low shrubby forest *M. australis* makes a close roof of greenery.

Freycinetia Banksii (Pandanac.), of *Pandanus*-form, clothes great trunks with its rooting stiff stems and yellow-blotched sword-like leaves. The root-climbing species of *Metrosideros* also play a most important part in draping trunks and tree-fern stems. *Clematis indivisa*, when in bloom, forms dazzling sheets of white on low trees and tall shrubs.

j. The species of Astelia (Liliac.). (Plate XXI, XXII, Fig. 27, 29.)

Several species of *Astelia* are prominent objects in the forest, especially those perched high on the branches of trees, 18 m or more from the ground, and looking not unlike gigantic birds' nests.

The forest-species are densely tufted herbaceous plants of somewhat tussock-form, their leaves numerous, linear, coriaceous and green with sheathing bases covered with white silky hairs. *A. nervosa*, a ground-plant, is the most widely-spread. *A. trinervia*, another ground-species attains a height of more than 1 m, its leaves measuring 1.3 m by 2.5 cm, while the plants grow close enough to make dense thickets in the northern forests.

The flowers of all are dioecious, small, and in panicles on long stems. The fruit is a fleshy berry which is orange in *A. nervosa* but red in the other lowland species.

The genus comprises 15 species, of which 9 belong to New Zealand, 1 each to Australia, subantarctic America and Fiji and 3 to the Sandwich Islands.

k. Tree Ferns.

The various tree ferns through their astonishing abundance, as well as their form, are amongst the most striking of the lowland plants. There are 8 species[1]) belonging to the genera *Cyathea*, *Hemitelia* and *Dicksonia*, 6 of which are endemic. Large examples of *C. medullaris* are 15 m, or more high, and some of the other species attain considerable dimensions. The feathery leaves spread out radially, like gigantic umbrellas, from the summit of the trunk, but at different angles according to the species. *C. medullaris* is conspicuous through its jet-black, massive leaf-stalks; *C. dealbata* through the silvery under surface of the leaf; *D. squarrosa* through its slender trunk clothed above with the persistent bases of old leaf-stalks and *D. fibrosa* through its massive trunk covered closely with a mat of aerial roots and its covering above of persistent depending dead leaves. Sometimes there are extensive groves of tree-ferns, or even low forest of little else, and such forms a frequent and striking spectacle in the valley of the Wanganui where they have persisted in old Maori clearings and similar stations.

l. Ferns in general.

The smaller ferns are exceedingly conspicuous in many lowland formations, though forest is their principal home, where they occur in the greatest abundance not merely on the floor, and draping the fallen forest giants with a feathery mantle, but climbing to the summits of the loftiest trees, or perching high on the spreading boughs. Moist gullies, dry slopes, trunks of tree ferns, rocks wet or dry, swampy spots, — all have their special species! (Plate XVIII, Fig. 23.)

Perhaps, the most important fern, physiognomically, of the forest and its environs, is *Blechnum capense*; its great pinnate leaves, bright or dark green in colour and 1.2 m long, arching downwards, cover completely, to the exclusion of all else, steep gully-slopes, faces of shale-rock and abrupt banks, the result of land-slips or man's operations, many square metres in area, the ground being altogether hidden. To this fern indeed do river-gorges owe much of their special beauty.

The total number of species of ferns in New Zealand, as a whole, is about 140, one half of which at most are of physiognomic importance.

2. Heath Plants.

a. Leptospermum scoparium Forst. (Myrtac.) Manuka, Kahikatoa, Tea-tree, Red tea-tree.

The manuka is both a small tree and a shrub[2]), but the latter form is alone of physiognomic importance so far as heath is concerned. It is an erect

1) There are in addition two other species in the Kermadec Group.

2) The plant is eminently plastic and even forms rooting mats upon the ground; it also can blossom when only a few centimetres high. Isolated plants with red or crimson flowers, as

shrub, of more or less fastigiate habit, very variable in stature, but finally attaining 3.6 m, or more. There is a fairly stout main-stem covered with reddish-brown bark which may hang in ribbons. The branches are slender, more or less vertical and finally give off numerous close-growing twigs bearing abundant small, aromatic, dark-green, lanceolate to ovate, pungent-pointed leaves, 5—12 mm long, which in mass are greyish. The flowers are on much-reduced shoots in the leaf-axils; they are white, 1 cm or more in diam. and produced in the greatest profusion. The capsule is woody, sunk in the calyx-tube, contains abundance of minute brownish seeds, and is persistent for some years, capsules of various ages together with flowers being present at the same time.

b. Pteridium esculentum (*Forst f.*) *Cockayne* (*Filices*), *Rau-aruhe*, *Bracken.*

Possibly this fern is rather a variety of the cosmopolitan *P. aquilinum*, but it is confined to the Southern Hemisphere, and it is convenient to name it as above. Its growth-form is too well-known to need description. The leaves are frequently more than 1.75 m long. They are exceedingly plastic and vary in structure from xerophytic to hygrophytic according to environment and from ordinary foliage-leaves to a liane-like habit. Since the advent of the white man the bracken has much increased, so that it must now be considered as one of the most aggressive weeds.

3. Steppe Plants.

a. Tussock Grasses.

The tussock grasses of lowland steppe are, — *Poa caespitosa* Forst. f., (also found in Australia); *Festuca novae-zealandiae* (Hack.) Cockayne (endemic) and *Danthonia Raoulii* (endemic and lowland only in South Otago and Stewart districts).

The growth-form exactly resembles the head of an old-fashioned besom. Culms and leaves are tightly bunched together, and, extremely tight at the base, are looser above and spread or droop to some extent laterally. The apical portions of the leaves are frequently dead and there is also much dead material within the tussock. The roots in part descend very deeply, but there are also short roots which penetrate merely the basal dead material which is retentive of moisture. *F. novae-zealandiae* and *P. caespitosa* are ecologically identical; they are about 40 cm high and their leaves very narrow and strongly involute, though in some forms flat.

D. Raoulii forms much larger, less compact tussocks than the above, some 75 cm high, which at the dense base may be about 30 cm in diam., and at the spreading arching portion above 60 cm or more through. The leaves

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also a double white, have been observed in the wild state, and there is reason to think such are at least semi-mutants. The "species" is a collective one consisting of numerous elementary species and probable hybrids. It occurs also in Australia, but possibly in different forms.

are narrow, but not filiform, stiff, thick, coriaceous, strongly involute, so forming a deep channel, and taper gradually to a long, filiform point; their colour is pale-green more or less tinged with red or orange. The leaf-sheaths are long, stout and persist long after the blade has rotted away, forming a close covering round the culm many times thicker than the living portion.

The tussock-grasses are gregarious and thus can stamp wide areas with the characteristic physiognomy they bestow. They are readily set on fire, a property which has led to great changes in the vegetation of much of New Zealand as detailed in Section V.

b. Cordyline australis (*Forst f.*) *Hook f.* (*Liliac.*), *Ti*, *Tikauka*, *Cabbage tree*, *Palm-lily.*

This species might equally well have been classified with the swamp- or even the heath-plants, for it can tolerate most soil-conditions. It is therefore a familiar object of the landscape generally[1]).

Its growth-form is that of a typical tuft-tree. The trunk is straight, erect, naked and covered with rough and fissured grey bark and attains an extreme height of 12 m, though usually less than half that size, with a diam. of 30 to 60 cm but even 1.5 m is recorded. The leaves are borne in a close tuft at the extremity of the trunk, the inner erect and semi-erect and the outer drooping. Young plants have leaves all up the trunk, but by degrees they die from below upwards, though still remaining drooping, brown and embracing the stem, until by the time the tree is about 3.6 m high they form a bunch merely beneath the living leaves. After flowering at about the age of 8 years the trunk divides and thus successive branches are formed until, in old trees, there is a spreading head of short limbs each crowned with its tuft of green leaves. Branches also may arise from other parts of the trunk and even from its base. The trunk is apparently continued beneath the ground, but this is not exactly the case, since during an early stage of seedling development, the subterranean portion (rhizome) originates from a lateral bud. From the rhizome which passes perpendicularly downwards, long lateral roots pass obliquely downwards so holding the tree firm. Besides functioning as a tap-root the rhizome is a storage organ for starch, on the supply of which depends in some measure the blooming of the tree.

The leaves are ensiform, 60—90 cm long and 3.7—5 cm broad, thick, coriaceous, pliable and sheathing at the base.

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1) Were a popular vote to be taken as to which plant most affected the general physiognomy of a New Zealand landscape either *C. australis* or *Phormium tenax* would undoubtedly be chosen, and certainly the striking form of both is frequently met with, even yet, in the lowland area, while their universal cultivation in New Zealand gardens makes them still more widely known. And yet they do not rule the landscape to anything like the same extent as do the tussock grasses in the S., the manuka, the bracken, nor, if a combination of plants be compared, the rain-forest. All the same, an isolated patch of the *Cordyline*, or a grove in some swamp, would at once attract the attention of a stranger from a temperate land.

The flowers are small, 4—5 mm in diam., very numerous, crowded, white, strongly scented, highly attractive to flies and borne on huge, erect or drooping panicles at the apex of the trunk, 60—120 cm long and 30—60 cm in diam. The berries are white, globose, fleshy, 6 mm in diam. and a favourite food of certain birds. The seeds germinate rapidly.

4. Swamp and Bog Plants.

a. Phormium tenax Forst. (Liliac.), Harakeke, New Zealand Flax.

P. tenax is a tall *Iris*-like herbaceous plant forming somewhat bunched-together rather tussock-like masses of erect or partly drooping leaves and occurring gregariously in swamps, fringing the banks of water-courses, or in clumps on hillsides, dunes or rocky places.

The leaves are 1—2.5 m, or more long by 6—12 cm broad, rather dull-green above, but somewhat silvery beneath, coriaceous, tough, flexible, but varying much in all these points; the margin is frequently stained brown. The major part of the leaf is flat, but at a greater or shorter distance from the base the two halves of the blade are folded together making a kind of petiole. There is a stout, creeping rhizome which branches near the apex, these bearing the leaves. The scape is stout, reddish-purple, often more or less glaucous with wax and it is raised above the foliage and bears numerous dull-red flowers 3—5 cm in length which are succeeded by dark-coloured erect or semi-erect capsules, 5—10 cm long filled with numerous black, oblong, shining, compressed seeds.

The species also occurs in Norfolk Island.

b. Arundo conspicua Forst. f. (Gramin.) Toetoe-Kakaho.

A. conspicua forms gigantic tussocks after the manner of the pampas-grass (*Gynerium argenteum*). The leaves are long and narrow, coriaceous, flat or involute and the nerves strongly developed. The rhizome is short but stout. The panicle, raised on a tall, stout stem above the foliage, consists of many yellowish drooping branches and renders the plant most conspicuous.

c. Typha angustifolia L. varr. Brownii (Kunth) Graeb. and Muelleri (Rohrb.) Graeb. (Typhac.) Raupo, Bulrush.

These forms so much resemble the European plant as to need no description here. It is the closeness of growth, the erect green leaves and, above all, the "bulrush"-inflorescence which makes the plant so noticeable and separates it at a glance from the other denizens of a lowland swamp even distance.

Chapter III. The Biology of the Lowland Plants.

1. Growth-Forms.

Here except when otherwise stated, only the 514 species of spermophytes and pteridophytes which are confined to the lowlands and lower hills are dealt with, since their biology should reflect more closely the ecological conditions than would that of the total lowland-lower-hill flora embracing, as it does, many species common on the high mountains.

a. Trees.

There are 77 species of trees of which 13 are tall (24 m and upwards), 11 medium (15—18 m) and 53 small (6—12 m or even less) while at least 30 occur also at times in the adult-form as shrubs. Nearly all the trees are evergreen, only 8 species being deciduous or semi-deciduous.

The following are the growth-forms and the number of species in each: — Tuft-tree 9, of which 6 are tree ferns and 2 branching[1]); canopy-tree 33; bushy-tree 27; araliad 5; tree-composite 2; leafless-juncoid 1[2]). In 27 species there is a juvenile form quite distinct from that of the adult and, in most cases, persisting for many years. The two most striking cases are where the juvenile is a divaricating shrub (7 species) or where there is an erect unbranched, or almost unbranched stem furnished with leaves much longer and narrower than those of the adult (9 species[3]).

Regarding the tree-trunks, those of no less than 40 species rarely exceed 30 cm in diam., and in some cases are much less; those of 15 vary from about 30 to 60 cm; those of 8 reach above 90 cm and, finally, 14 species have specially massive trunks more than 1 m[4]) in diam. (Plate XVIII, Fig. 24.) In some

1) A few cases are recorded of branching in the palm (*Rhopalostylis sapida*). For figure &c. see CHEESEMAN, T. N. 2. I. 1910: 209.

2) The endemic *Chordospartium Stevensoni.*

3) This is carried to an extreme in the well-known cases of *Pseudopanax crassifolium* and *P. ferox*. In the first-named, there is a primary stage with stalked, coarsely-toothed, rhomboid or almost lanceolate leaves cuneate at the base and some 6 mm to 5 cm long which may be considered reduced adult-leaves. By degrees as the main-stem lengthens, the leaves become narrower, until finally there is the second stage with a stiff, straight, slender, erect stem bearing, in a spiral, the long, deflexed, hard, thick, narrow, saw-toothed, sessile leaves which may measure 15—90 cm in length and are furnished with a very stout broad midrib. This second stage persists for 12 to 15 years or upwards, when the stem branches above and by degrees the succeeding leaves widen, shorten, acquire petioles and ultimately assume the adult linear-oblong to linear-obovate form 7.5—20 cm in length and the tree itself acquires a close rounded head. In the var. *trifoliatum* the third stage has 3—5-foliate leaves. In *P. ferox* the primary leaves are from the first of the narrow, toothed, rigid form; by degrees they lengthen and a second stage is entered similar to that of *P. crassifolium* but the margin is furnished with large, irregular, acute, hooked teeth. The further progress is similar to that of *P. crassifolium*. Reversion-shoots of the second juvenile form are produced at times from the base of the tree in cases of regeneration.

4) *Agathis australis* may reach 6.6 m, *Laurelia novae-zealandiae* and *Metrosideros robusta* 2.4 m and *Podocarpus totara* 1.8 m.

species the bases of the trunk may be more or less swollen or buttressed. True plank-buttresses, 1.8 m high by 12.5 cm thick, occur in *Laurelia novae-zealandiae* and more rounded ones in *Beilschmiedia tawa* and *Podocarpus dacrydioides*. In the tall and medium-sized trees the trunk is frequently unbranched for about $^2/_3$ of the height of the tree. In the greater part of the species the bark is thin, but bark 12 mm or more thick occurs in some species (*Agathis*, spp. of *Podocarpus* &c.).

The degree of density and of spread of the tree-crowns is largely a matter of environment. A very considerable proportion are dense and rounded while but few have really far-spreading branches. *Podocarpus dacrydioides* has a very sparse, narrow crown, small out of all proportion to the size of the tree. *Knightia excelsa* is almost as fastigiate as the Lombardy poplar and it shows up distinct from the general forest-mass. The head of *Metrosideros robusta*, though rounded and somewhat wide-spreading, is not dense owing to the leafy portion of each branch not intermingling.

The roots of the trees rarely descend deeply but spread out horizontally for a great distance and the uppermost, in some species, are only half-buried or, at times, raised above the ground-surface. Nodules are abundant on the roots of the *Pinaceae*, *Taxaceae* and *Leguminosae*. *Rhopalostylis* gives off short reddish stilt-roots at 30 cm or more from the base of the trunk. The tree ferns have a mantle of aerial roots surrounding their trunks. The base of the trunk may thus be much swollen, e. g. in *Cyathea dealbata* the base may measure 46 cm in diam. while it is not until a height of 56 cm from the ground is reached that the trunk is of the general diameter of 15 cm. In leaning trunks of the above fern large wedge-shaped masses of aerial roots frequently jut out from the under-surface.

The leaves of the trees are: — Simple 56, compound 20, broad 65, narrow 8, cupressoid 3, glabrous 64, more or less hairy 12 of which 7 are tomentose beneath and waxy beneath 7. Their dimensions are: — Very small (2.5 cm and less in length) 11; small (2.5 cm to 5 cm) 13; medium (5 cm to 10 cm) 30; large (10 cm to 20 cm) 12 and very large (20 cm and upwards) 10. These latter include the palm and the tree-ferns, the leaves of which frequently exceed 2 m in length and in the case of *Cyathea medullaris* may reach 6 m long by 1.5 m broad. As for the texture of the leaves those of 30 species are thin and of 46 more or less thick and coriaceous. The leaves of 22 species are glossy. As for the time of leaf-fall of the species of *Sophora* and *Hoheria sexstylosa* this has no relation to increase of cold but takes place just before the tree is going to bloom, while the new leaves appear as soon as the blooming is over. *Myrtus bullata* has curious reddish-brown, broadly-ovate leaves 2.5 to 5 mm long, concave beneath, but above the surface between the veins is raised in blisters, but sun-leaves are browner and more blistered than shade-leaves. Many of the thin-leaved species are plants of the forest-interior, a few are deciduous and others waxy or tomentose on the under-surface.

b. Shrubs.

There are 74 species of shrubs 67 of which are erect and spot-bound, 7 wandering, 35 tall (3 m or more), 22 of medium height (1 m—3 m) and 17 small (less than 1 m). About 46 species may be considered mesophytes and 28 semi-xerophytes or, in a few cases, xerophytes, these two latter plants of the open though a few occur also in the forest. Some 17 species pass through a distinct juvenile form but in most cases this does not persist for any notable length of time[1]).

The following are the growth-forms of the shrubs and the number of species to each: — Bushy-shrub 19; divaricating-shrub 14; flat- or round-stemmed leafless 10; erect straggling 7; semi-ball-like 7; shrub-composite 6; prostrate 3[2]); creeping with subterranean rhizome 2; *Dracophyllum*-form 2; tuft-shrub 3 (2 ferns[3])) and bamboo-form 1 (with stout rhizome).

The branchlets of the shrubs may be divided into, — stiff or wiry 30; slender or twiggy 26 and moderately stout 15. The bark is, in nearly all cases, quite thin. The trunk of *Blechnum Fraseri* varies from about 30—70 cm in height and is not thicker than a moderately stout walking-stick. From its base numerous runners pass off extending horizontally just beneath the surface of the ground and at a distance of some 10 cm a young plant is produced which develops first a trunk and then runners so that extensive, dense colonies are formed by vegetative increase alone. The trunk of *Todaea barbara* is short but massive and thus quite unlike the tall, slender trunk of a typical tree-fern.

Many of the shrubs, especially the xerophytes, root deeply. The species of *Veronica* readily produce adventitious roots from near the bases of the stems, so that a shallow-rooting mass of roots is formed.

The leaves of the shrubs may be characterised as follows: — compound 7, simple 57, very small[4]) 30, small 14, medium 10, large 7, very large 3, thick or coriaceous 37, thin 27, glabrous 43, hairy 21 (tomentose 13), glossy 6, deciduous 4, cupressoid 2, grass-like 2 and ericoid 5. The deciduous shrubs are 2 species of *Carmichaelia* and 2 species of divaricating *Olearia* all of which lose their leaves in the autumn.

c. Lianes.

Here, not merely the purely lowland species are dealt with, but all that occur in the lowland-lower-mountain belt. The New Zealand lianes are of peculiar interest since they are not only numerous and of great physiognomic

1) The xerophytic leafless spp. of *Carmichaelia* pass through a leafy mesophytic stage; *Melicope simplex* and *Nothopanax anomalum* have ternate leaves as seedlings and *Dracophyllum Urvilleanum* has wider, more spreading leaves when juvenile.

2) Several herbaceous ferns frequently develop trunks, especially (taking the lowland-mountain ferns also into consideration): — *Blechnum discolor, B. fluviatile, Dryopteris pennigera* and *Leptopteris superba.*

3) The other 2 wandering are included in bamboo and tuft-shrub forms.

4) The dimensions as for the trees, but in all cases the area of the leaf-surface is considered, so leaves longer or shorter than the specified length may be included.

importance, but many bear the true tropical stamp while the climbing *Myrtaceae* are autochthonic. The total number of lianes is 47 belonging to 16 families and 22 genera; 12 are scramblers, 13 root-climbers, 13 winders and 9 tendril-climbers while 33 are woody and 14 herbaceous. All the woody species, except 1, are endemic.

Scramblers.

This class[1]) is but little removed from many woody plants of the forest-interior which lengthen their internodes considerably and assume a spindling habit. For example *Fuchsia Colensoi*, always a twiggy bushy-shrub in the open, is, at times, in the forest, a high-climbing scrambler. The fern *Gleichenia circinata* is also a facultative liane, but rather on account of its fortuitously possessing plagiotropous pinnae suitable for climbing organs than on account of any external stimulus. More differentiated is the coastal *Angelica geniculata*, since not only are its stems too slender to stand erect but they are flexuous and approach the winding-form. *Helichrysum dimorphum*. exhibits a still more lianoid form in its flexible, cord-like, unbranched climbing-stem and its eventual close head of leaf-bearing twigs. But the highest degree of differentiation is shown by the different species of *Rubus*, since their leaves, more or less reduced to midribs furnished with hooked prickles, are special climbing organs, which cling with the greatest tenacity to anything they touch.

Rubus australis, the most common species, is, at first, a small erect plant; then, as it increases in strength, it puts forth long, stout, succulent, erect, prickly stems which become entangled in some neighbouring shrub. The growth then becomes more rapid and the stem continually ascending, and fixed firmly by its prickly midribs, may eventually gain the forest-roof, the climbing stem losing prickles, leaves and lateral branches, increasing in thickness, getting clad with rough bark and no longer resembling the smooth, green-stemmed juvenile form. Up in the tree-tops many lateral shoots are produced and those, alone leafy, bear abundant flowers and fruit. Finally, the swaying of the tree-tops, the weight of the plant, and other factors, loosen the stem from its supports, so that it depends, rope-like, from the forest-roof, swaying in the air, or in part, sprawling on the ground. Such, too, is the final history of various other woody lianes whose stems, free from any support, appear to hang down rather than to ascend.

The closely-allied *R. schmidelioides* shows an apparent connection between the prostrate and climbing forms, since, for a long period, the thin-leaved hygrophytic juvenile makes no attempt to ascend, but, rooting and creeping, forms extensive colonies on the wet forest-floor.

All the species of *Rubus* where there are no supports available form great rounded shrub-like masses.

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1) It contains 3 ferns, 1 woody grass, 5 species of *Rubus* 1 *Carmichaelia*, *Fuchsia Colensoi* and *Helichrysum dimorphum*.

The leaves of the scrambling lianes are as follows: — Compound 9, simple 3, very small 2, small 2, medium 5, large 2, very large 1, coriaceous 7, thin 5, tomentose 1, glossy 1, grass-like 1.

Root-climbers[1]).

Root-climbers are not confined to trees and shrubs as their hosts but cover the faces of rocks and also frequently creep over the ground. In the case of the ferns, it is hardly feasible to separate the climbing from the epiphytic, because many which have no connection with the ground ascend tree-trunks. *Polypodium diversifolium* possessing a thick, green, fleshy stem is equally a ground-herb, a liane and an epiphyte. *Blechnum filiforme*, *Arthropteris tenella*, *Polypodium pustulatum* and *P. novae-zealandiae* are almost obligate lianes. The first-named is a most characteristic object in the northern and central forests, its great pinnate leaves draping the trunks of the smaller trees and projecting outwards and downwards; the climbing stem is stout and woody, branches freely, surrounds the trunk of the host and, at times winds to some small extent. The juvenile plant creeps on the ground and has much smaller leaves and differently shaped leaflets to those of the adult.

Freycinetia Banksii has a terete, hard, woody, rigid stem, 2.5 cm or so in diam. fastened to the host by stout roots which pass quite round a slender trunk and finally branching copiously cling most closely to the bark. The leaves are sword-like, 60 cm or more long, thick, coriaceous, glabrous and may quite hide the tree-trunk.

The species of *Metrosideros* have stout, woody climbing stems which ascend the loftiest trees and are, at first, fastened tightly to the host by numerous aerial roots. Lateral branches are given off freely: these, at first soft and fleshy, grow rapidly but put forth no roots until woody, the apical portion being without roots and having only partially developed leaves. The climbing shoots are pressed more or less tightly against the bark, *M. scandens* being most marked in this regard the small, thick, roundish leaves being pressed tightly against the bark forming typical leaf-mosaics. Finally, in all the species, lateral non-climbing shoots are developed which can bear flowers and fruit, their leaves more or less distinct from the juvenile. The main climbing stems, in the highest-climbing species, eventually lose their roots, are held away from the trunk and increase in thickness attaining, in *M. florida*, a diam. of 15 cm. All the climbing species of *Metrosideros* at first creep on the forest-floor partly above and partly below the surface and put down roofs in abundance. Such stems may be dozens of metres in length but when they reach a tree climbing shoots with holding-roots may be put forth and thus lianes far-distant be really parts of one plant. *M. florida*, *M. albiflora* and especially *M. scandens* occur also as ground-shrubs (Plate XIX, Fig. 25).

1) This class contains 1 filmy fern, 5 ordinary ferns, *Freycinetia Banksii* and 6 species of climbing *Myrtaceae*.

Winding lianes[1]).

The climbing stems are usually quite slender and so can make use of small shrubs and young trees in order to raise themselves in the first instance, but these are frequently killed by the increasing pressure of the winding stem and the number that thus succumb must be indeed great. Sometimes for many square metres at a time the black stems of *Rhipogonum scandens* form close entanglements no trace remaining of the original host-plants.

Lycopodium volubile is an interesting example of the transition of a creeping ground-plant to a winding-liane by way of a scrambling plant. This plant, as a creeper, in many places extends its slender, woody, stiff stems far and wide, rooting in the soil and raising them unsupported for 60 cm, or so, into the air. Thus a prop may be gained, and this happening, the method of climbing depends upon the nature of such. If the support be twiggy, the liane merely scrambles through the branches, its lateral branchlets at about a right angle to the axis, the sporophyll-bearing branches and the hook-leaves of the stem all functioning as climbing organs, the last-named also aided by the flexuous stems. Where the support however is smooth and with few projections, the stem of the *Lycopodium* twines strongly gripping the support tightly[2]).

In the case of *Senecio sciadophilus*, a true winding liane, the stems, when on the ground, put forth long roots in abundance, branch, extend over a considerable area, bear abundance of leaves, and are, in fact, creeping plants pure and simple. The occasional winding of the root-climber *Blechnum filiforme*, when the support is specially slender, may also be cited. A few others of the winding lianes demand brief mention.

Rhipogonum scandens at first puts forth a stout, succulent fast-growing stem from its root-stock sparingly furnished with a few scale-like dark-coloured leaves, but the mature climbing stem gives off non-climbing branches which bear large, green, oblong, coriaceous leaves. The winding-fern, *Lygodium articulatum*, forms masses of wiry, slender, brown, extremely tough climbing-stems which wind round one another as well as the branches of the support. These stems are morphologically leaf-spindles of unlimited growth. A frond thus may attain the great length of 40 m, but frequently the liane is confined to shrubs or low trees. The first 2 or 3 fronds never climb and are only about 12 cm high; probably their function is to construct food for the succeeding climbing-frond. The primary pinnae pass off from the spindle alternately at a distance of about 14 cm; they are bright-green, glossy, rather thin and covered on the under surface with a coating of wax; their rhachis may continue to extend, or the bud at its apex remain dormant. The two species of *Muehlenbeckia* are extremely leafy, *M. australis* covering low trees with a dense mass of verdure. The stems of the 2 species of *Parsonsia* are slender

1) These include 1 fern, 1 lycopod, 6 woody spermophytes and 5 scandent herbs.

2) The above is partly drawn up from an excellent detailed account kindly sent to me by Mr. ESMOND ATKINSON.

and pliant and frequently wind not only round the host but round themselves Both species show most remarkable heterophylly there being three distinct leaf-forms at different stages of the plant's development.

The adult leaves of the winding lianes consist of: — Compound 1, simple 12, thick or coriaceous 4, thin 9, glabrous 10, hairy 3, glossy 2, waxy beneath 1, very small 2, small 7, medium 3 and large 1.

Tendril-climbers.

This class contains only the 8 species of *Clematis* and the monotypic *Tetrapathaea australis*. All are lianes with comparatively slender much branching stems draping low trees and shrubs, rather than lofty climbers. *Tetrapathaea* is in habit and appearance very similar to *Parsonsia heterophylla*, forming dense masses of flexible, slender branches bearing abundant dark-green, glossy, somewhat coriaceous, ovate-lanceolate, acuminate leaves some 5 cm long. The tendrils, at first straight and soft, and slightly curved near their apices, finally become stout and wiry. The species of *Clematis* form a series of transitions from a thin-leaved mesophyte by way of sub-xerophytes with much-cut reduced leaves to the leafless juncoid *C. afoliata*, which forms either rounded strongly entangled masses of slender, green, flexible stems on the ground or climbs over low trees or shrubs.

d. Epiphytes.

In this section all the members of the class, excepting the purely coastal epiphytes, are dealt with. Strictly speaking, an epiphyte is a plant that should be invariably found seated upon another. This, in New Zealand, is true only for certain ferns, almost all *Hymenophyllaceae*, bryophytes, lichens and a very limited number of spermophytes. These latter are nearly always to be found also on rocks and some are common ground-plants. Thus *Senecio Kirkii*, a shrub 3.6 m high, somewhat candelabrum-like in form, with slender, spreading branches and dark-green, soft, rather fleshy, lanceolate leaves some 7 cm long in rosettes, is frequently terrestrial in Kauri forest and epiphytic in taxad. *Metrosideros robusta* usually commences life as an epiphyte on the loftiest trees, puts roots to the ground as its water-balance fails, these eventually surrounding the host, crushing it to death, growing more or less into a solid mass and functioning as a trunk. *M. lucida* and *Griselinia littoralis* behave similarly at times (Plate XX, Fig. 26), but the latter does not destroy its host, and the small tree, *Nothopanax arboreum*, frequently commences life as an epiphyte on a tree-fern.

About 38 species belonging to 8 families and 18 genera may be considered epiphytes. Their growth-forms are: — Filmy fern 13; tufted fern 5; creeping fern 3; pendulous semi-woody plant 2; erect unbranched semi-woody plant 1; epiphytic orchid 6 (pseudo-bulbous 2); tussock 2; prostrate surface-creeping herb 2; shrub 4.

The presence of the different growth-forms in any forest depends upon the conditions offered, while such are a matter of climate. Tree-fern trunks with a thick water-holding mantle of aerial roots offer suitable conditions for the germination of many young trees and shrubs and for the ramification of the slender wiry stems of the *Hymenophyllaceae*, some being confined thereto, others commoner there than elsewhere and others again equally at home on the forest-floor. The occurrence of many of the spermophytic epiphytes and the larger pteridophytes is bound up with the prior occupation of trunks and branches by epiphytic bryophytes which, in their turn, occupy their epiphytic station thanks to the water-absorbing capacity of their leaves, the sponge-like cushions, mats or masses they build so rapidly and various special water-holding contrivances. Soon sufficient soil is formed from the decay of the bryophytes to support seedling epiphytes and these, each according to its specific capability, make more soil from its decaying leaves &c. until a surprising quantity of vegetable matter in various stages of decay accumulates on horizontal boughs and forks of branches amply sufficient to support shrubs and herbs of no mean size.

The epiphytic species of *Astelia* are of great physiognomic importance and also of peculiar interest, since they are ecologically equivalent to the tropical epiphytic *Bromeliaceae* and like them store up water. *A. Solandri* is a densely tufted evergreen herb with numerous, ensiform, coriaceous leaves 90 cm—1.2 m long with black, sheathing, fleshy bases covered with a great quantity of long silky hairs. These leaf-sheaths, even in quite dry weather, hold large quantities of water. The plant forms immense tufted masses high up on the tree-tops, the basal part and earlier leaves decayed and making a usually sopping-wet mass of loose vegetable matter. The plant frequently grows on slender perpendicular trunks in what appears an impossible position for a plant so massive and heavy (Plate XXI, Fig. 27).

Pittosporum Kirkii and *P. cornifolium* are sparsely-branched straggling shrubs with long, flexible branchlets, those of the latter being slender and drooping. The leaves of both are coriaceous but those of *P. Kirkii* are extremely thick.

Griselinia lucida is, at times, almost a bushy-tree with thick, furrowed bark. The leaves are obliquely-oblong, thick, coriaceous, bright-green, glossy and 7.5—17 cm long. Although an obligate epiphyte, or rock-plant, it grows luxuriantly in ordinary garden conditions.

The leaves of the epiphytes are as follows: — simple 21; compound 17; very small 7; small 9; medium 9; large 8; very large 5; thick or coriaceous 23; thin 15; very thick or succulent 6; glabrous 33; hairy but to no extreme degree 5; grass-like 3. A few details as to the leaf-anatomy as shown by a transverse section may be given. *Pittosporum cornifolium* is fairly xerophytic with a thick cuticle on both surfaces, a very large-celled subepidermal water-tissue and dense mesophyll with few air-spaces; on the other hand the palisade, only 2 cells deep, is poorly developed. *Astelia Solandri* also shows xerophytic structure in the very thick cuticle and the mesophyll, much of it colourless or almost so, with few air-spaces. *Senecio Kirkii* (not a forest-roof epiphyte and facultative merely) is of marked mesophytic structure except for its large-celled subepidermal water-tissue. *Dendrobium Cunninghamii* has moderately thick cuticle; the upper epidermal cells are remarkably large and the mesophyll is undifferentiated and consists of spheroidal cells their long axis parallel to the epidermis.

e. Parasites.

Here, for convenience, all the New Zealand higher parasites are dealt with numbering 17, of which 11 are shrubs and 6 herbs [1]).

The shrubby species differ in height, 1 reaching more than 3 m, 3 more than 1 m, 2 about 90 cm and 5 not more than 15 cm. In habit 5 are dense bushy-shrubs, 1 open and rather straggling and, of the small species, 2 are generally but little branched but the other forms tufted masses. All are hemi-parasites; none are restricted to one host [2]). Biologically these shrubs fall into two classes, the one where the seedling at once sends down a root into the tissues of the host and the other where this does not happen but a lateral root is developed which eventually branches, and, at intervals, puts suckers into the tissues of the host, while at such points aerial shoots may also arise. To the second class belong *Loranthus* and *Elytranthe* and to the first the endemic *Tupeia* and *Korthalsella*. In all cases, the main shrub occurs where the seed has germinated. In the case of *Loranthus micranthus* the lateral root may follow the course of a branch or it may also descend the main stem and eventually reach the surface of the ground, the descending root resembling in appearance a liane. Occasionally the root-tip may leave the branch altogether in which case it does not descend to the ground but bends back towards the branch. Where the suckers enter the host considerable swellings occur. The species of *Loranthus*, *Elytranthe* and *Tupeia* are abundantly leafy, those of *Korthalsella* are leafless. The leaves of 5 of the species may reach 7 cm in length, but of 1 only 3 cm; in all cases they are green and glabrous and, except for *Tupeia*, thick and coriaceous. The stems of *Korthalsella Lindsayi* and *K. clavata* are jointed and flattened, the joints 8 cm or more long by 5 cm or so broad, coriaceous and dark-green. *K. salicornioides* has also jointed stems but they are succulent, virtually terete and only about 1 mm in diam. Two of the species of *Elytranthe* have extremely showy scarlet flowers.

The herbaceous parasites belong to three distinct classes; all are holoparasites. The 3 species of *Gastrodia* are earth-orchids with slender, straight, erect, unbranched, pale-coloured stems varying, according to the species, from 30—90 cm or more in height and extremely long, brittle, fleshy tuberous roots which are parasitic on the roots of certain forest-plants.

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1) *Phrygilanthus tenuiflorus* and *P. Raoulii* have been seen by no living N. Z. botanist either *in situ* or as herbarium specimens; so, though included in the above total they are excluded from what follows.

2) *Loranthus micranthus* is not only parasitic on a number of indigenous species but also on certain introduced trees, e.g, — the plum, pear, poplar, laburnum &c. *Tupeia antarctica* is occasionally parasitic on *L. micranthus* and *Elytranthe tetrapetalus* (see Kirk 1876: 329). *L. flavidus* is perhaps restricted to *Nothofagus cliffortioides* and *N. Solanderi*.

Dactylanthus Taylori, according to CHEESEMAN, is parasitic on the roots of *Schefflera* and less frequently on those of *Nothopanax arboreum*, *Rapanea Urvillei*, *Pittosporum* and *Nothofagus*. There is a perennial, fleshy, tuberous rhizome resembling, according to HILL (1909 : 439), a large potato covered over with warts, which varies according to age from less than 2.5 cm to more than 30 cm in diam. In the earliest stages of development observed, HILL states that the ends of the most delicate roots are selected by the parasite and that the young rhizome resembles a wart on the human hand. The monoecious flowers are produced on fleshy aerial stems, annually renewed, at most 15 cm high.

Cassytha paniculata is a twining, leafless plant having for its host shrubby species of the 'gumlands' heath e. g., *Leptospermum scoparium*, *Pomaderris Edgerleyi*, *Cassinia amoena* &c., to which its slender, very stout, pale stems are attached by means of suckers. These stems pass tightly stretched from plant to plant, so that one may easily trip over them. The supposed indigenous *Cuscuta densiflora* needs no special description.

According to KIRK (1889: 138) *Fusanus salicifolia* is during one stage of its existence a root-parasite.

f. Water-plants.

No line of demarcation can be drawn between water and swamp plants. The species of *Myriophyllum*, here included, could be quite well transferred to the latter class. Here both the purely lowland and those species ascending to the high-mountain belt are dealt with.

The species number 20 which fall into the two divisions, — free-floating (5 species) and rooting (15 species). Taking the latter class first, it comprises the growth-forms as follows together with the number of species in each: — submerged 6 including rush-form 3, grass-like form 1, ribbon-form 1 and mat-form 1; floating 7 including entire-leaved 5 and cut-leaved 2; partly submerged partly aerial 2.

The free-floating consists of *Azolla rubra*, 2 species of *Lemna* and 2 of *Utricularia*.

g. Herbs and semi-woody plants.

The number of species of this class confined to the lowlands is 287 of which 117 are wandering and 170 spot-bound, 17 being annuals or biennials, 41 summergreen, 246 evergreen, 17 semi-woody and 270 herbaceous. With regard to the stature of the species 20 are very tall (more than 90 cm), 39 tall (60—90 cm), 37 of medium height (30—60 cm), 83 small (15—30 cm), 108 very small (less than 15 cm) of which 44 hug the ground or are, at most, 3 cm tall. About 266 species may be considered mesophytes and 21 xerophytes, but only a few of these can be considered much more than subxerophytes[1]).

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1) e. g. — *Scirpus nodosus, Thelymitra pachyphylla,* the 2 species of *Peperomia, Anisotome flabellata* and *Myosotis albosericea.*

The growth-forms and the number of species belonging to each are as follows: — 1. Annuals and biennials 17 including, — tufted-fern 1; tufted-grass 2; mat-form 2 (non-rooting 1, rooting 1); rosette-form 1; erect-branching 10 and semi-erect branching 1.

2. Perennials 270 divided into: — a) Wandering (117), — α) semi-woody, — mat-form 1, — β) herbaceous, mat-form 57 including herb-mat 43, grass-mat 2, rush-mat 2, fern-mat 10 (filmy 8); erect-creeping form[1]) 43 (fern 29, herb 6, grass 5, rush 3); orchid-form 10 (summergreen); straggling-form 1; herb-turf 1; *Utricularia*-form 2 and *Iris*-form 2. b) Spot-bound (153), — α) semi-woody, — erect-branching 10; tuft-fern 3; rosette-form 3. — β) herbaceous, — tufted-form 50 including tufted-fern 24 (filmy 2), tufted-rush 13, tufted-grass 13; tussock 25 (grass 19, rush 6); erect-branching 15; rosette-form 10 (herb 9, grass 1); mat-form 3; orchid 27 (summergreen); straggling-form 2; *Iris*-form 4; holosaprophyte 1.

The saprophyte (*Bagnisia Hillii*) according to CHEESEMAN (1909 : 141, 142) is found in decaying leaves and humus at the base of *Podocarpus dacrydioides*. There is a branching, fleshy rhizome 5—10 cm long and 1—1.5 mm thick. Leaves are wanting and the vegetative parts are colourless. One-flowered peduncles, 5 mm to 15 mm in length, are given off from the axils of the minute fleshy bracts. The flower is rose-pink and about 1.5 cm long by 7 mm broad.

The leaves of the herbs &c. may be characterized as follows: — compound 83; simple 190 (leafless or nearly so 14); thin 206; coriaceous or thick 67; glabrous[2]) 225; hairy 48 (tomentose 7). Regarding their size 26 are very large (20 cm in length and upwards), 32 large (10—20 cm), 49 medium (5—10 cm), 97 small (2.5—5 cm) and 69 very small (2.5 cm or less).

Generally speaking long, deeply descending roots are rare while comparatively short roots are quite common.

2. Pollination.

Considering only the species confined to the lowlands and lower hills and leaving on one side the wind-pollinated Gramineae &c. the total number to be dealt with is 342 of which the flowers of 62 p. c. may be considered monoclinous and those of 38 p. c. more or less diclinous (dioecious 57 spp.; monoecious 10; polygamous but in some cases dioecious or monoecious 60). But these figures do not sufficiently emphasize the importance of allogamy, for many hermaphrodite species are dichogamous but I can supply no reliable details as to protandry &c.

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1) Here are included those plants with far-extending rhizomes which give off abundant erect shoots or leaves so that in time a close, erect even mass is produced, e. g. — *Pteridium esculentum*.

2) Here and elsewhere leaves slightly hairy are included under glabrous for the statistics are physiological.

About 49 p. c. of the species, here being dealt with, possess fairly attractive flowers, but those of the remainder are generally both dull in colour and very small. The attractive flowers are of the following colours: — white 81 (48 p. c.), cream 4, yellow 31, orange 1, purple 26, lilac 3, blue 3, pink 9, red 5, scarlet 1 and green 4. In some cases the colours are combined, especially in the *Orchidaceae*, and the more brilliant colour, though less in area than the groundwork, may be far the more striking. The most showy flowers occur in the genera *Elytranthe*, *Clematis*, *Ixerba*, *Sophora*, *Pennantia*, *Hoheria*, *Metrosideros*, *Veronica*, *Olearia* and *Senecio*. At least 76 species (22 p. c.) are more or less sweet-scented but I have insufficient details, as also is the case with regard to nectar-flowers. There is no doubt however that insects play a most important part in pollinating the lowland plants. Certain of the species are pollinated in part or exclusively by birds and such is probably the case in the following species and genera some, by the bye, not purely lowland, — *Phormium*, *Knightia*[1]), *Clianthus*, *Sophora*, *Metrosideros florida*, *M. lucida*, *M. robusta* and perhaps other species, *Fuchsia excorticata*, *F. Colensoi*, *Vitex*[2]) and *Rhabdothamnus*[3]). Cleistogamy has been recorded by G. M. THOMSON in *Viola filicaulis*, *V. Cunninghamii* and *Melicope simplex*.

3. Seasonal changes.

Although there is a distinct response in New Zealand lowland plants to the seasons yet this is rather the result of long "habit" than of any truly great difference between summer and winter. It is true that in the great majority of species there is a longer or shorter winter resting period but, at the same time, there are species which find that season eminently suitable for the development of flowers. Thus during winter in the lowland forest the following are in full bloom: — *Dysoxylum spectabile*, *Nothopanax arboreum*, various species of *Coprosma* especially *C. grandifolia*, *C. robusta* and *C. spathulata*. During August a few northern species come into bloom in the North Auckland forest, especially, — *Sophora tetraptera*, *Pittosporum cornifolium*, *Rhabdothamnus Solandri* and *Alseuosmia macrophylla*. Even on the Canterbury Plain, a race of *Sophora microphylla* flowers during August. But whenever either of the above species of *Sophora* flowers just at the time of blossoming the tree loses its leaves only to have them replaced almost immediately. So too, the deciduous habit of *Hoheria sexstylosa* and *H. angustifolia* is correllated not with winter but with blossoming. On the other hand *Plagianthus betulinus* which comes into leaf from August to September, according to latitude, loses its leaves in the autumn as do also either completely or partially, — *Muehlenbeckia australis*, *M. complexa*, *Carmichaelia grandiflora*, *C. angustata*, *C. odorata*, *Aristotelia racemosa*, *Discaria toumatou*, *Gaya Lyallii*, *Fuchsia excorticata*,

1) See CHEESEMAN (Rep. Aus. Assoc. A. Sc. 1890).
2) See PETRIE 1905: 411.
3) See PETRIE T. N. Z. I. 1913: 264.

F. Colensoi, *F. procumbens*, *Olearia virgata*, *O. lineata*, *O. Hectori*, *O. odorata*, *O. fragrantissima* and *Senecio Hectori*.

If September, October and November be considered spring; December, January and February summer, and March, April and May autumn, then we may speak of early spring, mid-spring, late spring, early summer, late summer and autumn, as distinct divisions of the growing-season, each distinguished by certain species coming into bloom. According to those divisions the most floriferous period is late spring together with early summer or roughly speaking from the middle of October to the middle of January, the period opening and closing earlier in the N. than in the S. The following are some of the more characteristic species marking the divisions as above: — 1. (Early spring.) *Clematis indivisa*, *C. foetida*, *Drimys axillaris*, *D. colorata*, *Pittosporum eugenioides*, *Rubus australis*, *Melicope ternata*, *M. simplex*, *Aristotelia racemosa*, *Styphelia fasciculata*, *Geniostoma ligustrifolia*, various species of *Coprosma*, *Olearia Cunninghamii* and *Brachyglottis repanda*. 2. (Mid-spring.) *Agathis australis*, various *Taxaceae*, *Pittosporum tenuifolium*, *Leptospermum scoparium*, *Olea Cunninghamii* and *Olearia Hectori*. 3. (Late spring.) Various species of *Nothofagus*, *Clematis Colensoi*, *Beilschmiedia tawa*, *Ixerba brexioides*, *Carpodetus serratus*, *Weinmannia racemosa*, *Pennantia corymbosa*, *Discaria toumatou*, *Melicytus ramiflorus*, *Leptospermum ericoides* and *Nothopanax simplex*. 4. (Early summer.) *Phormium tenax*, *Cordyline australis*, *Dianella intermedia*, *Weinmannia sylvicola*, *Hoheria angustifolia*, *Gaya Lyallii*, *Metrosideros lucida*, *M. robusta*, *Dracophyllum longifolium*, *Olea montana*, *Parsonsia heterophylla*, *Veronica salicifolia*. 5. (Late summer.) *Arundo conspicua*, *Gahnia xanthocarpa*, *Astelia Solandri*, *Hoheria sexstylosa*, *Nothopanax Edgerleyi*, *Schefflera digitata*, *Dracophyllum latifolium*. 6. (Autumn.) *Astelia Cunninghamii*, *Earina autumnale*, *Bulbophyllum tuberculatum*, *Dactylanthus Taylori*, *Hoheria populnea*, *Metrosideros florida*, *Meryta Sinclairii*, *Pseudopanax crassifolium*, *Rapanea Urvillei*.

4. Epharmonic variation.

The more uniform conditions of climate ruling in the lowlands than on the coast or in the high mountains lead to less epharmonic variation and to greater uniformity in the associations. All the same, the amount of epharmonic change is striking enough. Here a few examples must suffice.

The same species within and without the forest has sometimes a very distinct appearance. Trees with long unbranched trunks may develope in the open as densely leafy trees. Many juvenile trees in the dense rain-forest develope a long liane-like stem branching sparsely near the apex only, but in the open the same stage of development would be represented by a bushy-shrub. A specially wet soil, or a moist atmosphere in the forest, can induce various morphological changes. Thus certain tufted ferns may develope distinct trunks; *Schefflera digitata*, an araliad with thin digitate finely-toothed leaves, in the ordinary course has its juvenile leaves similar to the adult, here the leaflets are deeply-cut and very similar to those of *Nothopanax simplex*; and divaricating-shrubs in general are much more open and with less rigid branches than if members of a dry forest, a scrub-formation or where exposed to high winds.

The relation between shrubs or creeping-plants and lianes has been already sufficiently elaborated. But in the case of *Rubus cissoides* var. *pauperatus* not only is the growth-form affected, but the leafless shrub-form of dry ground in the open has never been known to bloom whereas, when leafy in the forest, it flowers abundantly.

Leptospermum ericoides is a forest-tree some 12 m or more high with a trunk more than 70 cm in diam. but when growing near hot-springs exposed to a certain amount of steam it is a slender absolutely prostrate shrub and yet its companion-plant, *Styphelia fasciculata*, an erect shrub of forest or heath is here also erect though somewhat stunted.

Certain xerophytes are greatly changed by shade-conditions. Thus *Pteridium esculentum* growing in the feeble light of tall *Leptospermum* low-forest may become virtually a scrambling liane with a tendency to wind. *Gleichenia dicarpa* has the segments of its sun-leaves so bent as to form small pouches whereas the shade-leaves of the same individual will be flat. *Lycopodium ramulosum* of a Westland moor produces abundant sporophylls in the sun but is virtually sterile in the shade.

The deciduous habit, though constant in some species, in others only occurs where frosts are comparatively severe e. g. — *Muehlenbeckia australis*, *Aristotelia racemosa* and *Fuchsia excorticata* are deciduous or the contrary according to circumstances.

Chapter IV. The Plant Formations.

1. Forest.

a. General.

New Zealand, as a whole, owing to its high average rainfall of a fairly even distribution all the year round, and its equable climate, was originally covered from N. to S. with a close mantle of forest, except where the edaphic conditions were antagonistic, or the rainfall insufficient to meet the demand of the various transpiration-factors, especially wind. Even yet, settlement notwithstanding, considerable areas are clothed with noble forest, extending in no few places from virtually high-water mark to the subalpine belt. In north-western Auckland, on the Volcanic Plateau and the adjacent Wanganui coastal plain, on the slopes of the North Island mountains, on most of the land W. of the Southern Alps, in parts of the South Otago and Stewart districts, forests still exist in no whit different from those visited by the early botanists[1]).

1) Thanks to the Scenery Preservation Act of 1903, many areas in these localities, and elsewhere, have been permanently set aside for the preservation of the indigenous plants and animals. There are also several national parks of great extent and climatic reserves on the mountains that serve a similar purpose.

The forests fall naturally into the two classes of hygrophytic rain-forest and mesophytic southern-beech *(Nothofagus)* forest, but between the two there are transitions. Generally speaking, the lowland tree-associations are rain-forest, the species of *Nothofagus*, being wanting in many localities, or, if present, not forming pure associations.

The principal ecological conditions which govern New Zealand lowland-forest are: — 1. A rainfall exceeding 75 cm distributed more or less equally throughout the year. 2. A sufficient supply of available water at all seasons in the surface-soil. 3. A winter temperature not falling below — 10° C. 4. The special conditions brought about by the plants themselves, which define, in large measure, the wind, light, heat, air-moisture, soil-moisture and humus factors. These last-mentioned conditions come gradually during the evolution of forest and render possible the various phases of succession. Usually, the rainfall is far greater than as given above, but with its increase neither the ecological nor the floristic composition of a forest is greatly affected. The even distribution of rainy days throughout the year is a matter of prime importance, for a drought of several months duration will actually cause the death of several endemic species of trees. As for the heat-factor, each species has its special requirements and limitations, and the degree of cold, cited above, is far greater than many plants can tolerate.

The ecological conditions of any forest-area are far from uniform. Much depends upon the topography, — slopes, ridges, flats and gullies, each possess their special plant-coverings in harmony with the differences in ground-water, depth of humus, air-moisture, light-intensity and shelter from wind. An interesting case is presented by the forest of the Wanganui coastal plain, where, on the slopes, there is hygrophytic tawa *(Beilschmiedia tawa)* forest and on the ridges a pure semi-xerophytic association of *Nothofagus Solanderi*, even if these trees be almost in single file. Nor is the lowland forest, climax-formation though it be, in any great state of stability. As the dominant tall trees die, they are frequently replaced by another species, and forests may be seen in actual process of change. Thus, in Stewart Island, *Podocarpus spicatus* was formerly one of the dominant tall trees, but it is now almost wanting, *Weinmannia racemosa* having taken its place, the latter in many cases still embracing with its roots, now the trunk, the remains of the former trunk of the taxad. So, too, in the forest at the base of Mount Egmont, *Metrosideros robusta*, once epiphytic on *Dacrydium cupressinum*, is now a most abundant tree, and the taxad will ere long be altogether replaced, since there is hardly a tree that is not at some stage or other of strangulation by the epiphyte. Changes of the above character bring about marked differences in the light-relation and the undergrowth gradually alters in accordance therewith.

The lowland-forest, in all its modifications, consists of about 381 species of plants belonging to 62 families and 150 genera. The pteridophytes and spermophytes number respectively 91 and 290. The following are the most important families together with the number of species in each: — *Filices* 88;

Rubiaceae 27; *Cyperaceae* and *Orchidaceae* 22; *Taxaceae* and *Myrtaceae* 16; *Compositae* 14: *Liliaceae* 11 and *Araliceae* 10. The most important genera and the number of their species are as follows: — *Coprosma* 24; *Hymenophyllum* 16; *Blechnum*, *Pittosporum* and *Metrosideros* 9, *Carex* 8 and *Trichomanes*, *Asplenium*, *Podocarpus*, *Gahnia Corysanthes* and *Uncinia* 7. Leaving the pteridophytes on one side, 89 per cent of the spermophytes are endemic, while the greater part of the remainder are Australian. The following genera, all but 3 being monotypic, are endemic and confined to forest: — *Tupeia*, *Dactylanthus*, *Ixerba*, *Carpodetus*, *Alectryon*, *Hoheria*, *Tetrapathaea*, *Corokia*, *Teucridium*, *Rhabdothamnus*, *Alseuosmia* and *Colensoa*. Other endemic genera, but which occur in other formations, are: — *Loxsoma*, *Suttonia* and *Brachyglottis*.

The growth-forms of lowland-forest are: — Trees 99, shrubs 63, herbs 51, grass-like plants 26, ferns 88, lianes (excluding ferns) 26, epiphytes (excluding ferns) 15 and parasites 13. The ferns include 8 tree-ferns, 23 filmy ferns, 7 lianes and 17 epiphytes.

So far as physiognomy is concerned, there is a considerable resemblance between the various rain-forest associations throughout the range of the formation, but one rather ecological than floristic. This likeness is owing to the following circumstances: — 1. The presence of taxads with one or other of their species frequently dominating. 2. The great abundance of tree-ferns. 3. The vast number of ground-ferns (Fig. 28) many of which are of wide distribution, and the presence throughout in quantity of *Asplenium bulbiferum*, *Blechnum capense* and *B. discolor*. 4. The presence in abundance of the lianes *Muehlenbeckia australis*, *Rhipogonum scandens*, *Metrosideros hypericifolia* and *Rubus australis*. 5. The density of the undergrowth and the presence therein of certain low trees or tall shrubs, especially, — *Carpodetus serratus*, *Pittosporum tenuifolium*, *Melicytus ramiflorus*, *Myrtus pedunculata*, *Nothopanax arboreum*, *Schefflera digitata*, *Pseudopanax crassifolium*, *Rapanea Urvillei* and *Coprosma robusta*. 6. Shrubs of the divaricating growth-form being common in the undergrowth. 7. The abundance of filmy ferns, mosses, liverworts and foliaceous lichens.

Notwithstanding the facts of the preceding paragraph, there are many obvious distinctions that define, at a glance, the lowland-forest at different parts of its range. In proceding from N. to S. many characteristic plants give out gradually, each having its special southern limit[1]). The North Island forest, as a whole, together with that of the north of the South Island, is marked off from a typical forest of the Southern botanical province by the abundance of the lianes *Freycinetia Banksii*, *Metrosideros florida*, *M. scandens* and *Blechnum filiforme*, the palm *Rhapolostylis sapida* and to a lesser degree by certain trees, especially, — *Knightia excelsa*, *Laurelia novae-zelandiae*, *Rapanea salicina*, *Beilschmiedia tawa*, *Myrtus bullata*, *Melicope ternata*, *Olearia Cunninghamii*

1) Besides what follows more details are to be found in Part III, Chapter I, Sections 2 and 3.

and *Brachyglottis repanda*. The presence of *Freycinetia*, *Astelia Cunninghamii* and *Metrosideros florida* in the forest of the Western district clearly distinguish that association from the remainder of the forest of the Southern botanical province.

A census of the forest-species shows that in the Northern botanical province there are 311 (pteridophytes 85, spermophytes 226), in the Central 324 (pteridophytes 86, spermophytes 238) and in the Southern 292 (pteridophytes 78, spermophytes 214). Stewart Island, though a portion of the Southern province, contains only 155 species (pteridophytes 52, spermophytes 103). If the whole

Fig. 28. Late stage in evolution of vegetation near Franz Josef glacier, Western bot. dist. In foreground: — *Blechnum discolor* and *Leptopteris superba*. Photo L. Cockayne.

of the forest-area of the three islands be considered, the species which occur throughout number 134 (pteridophytes 50, spermophytes 84), but a number of these will be absent in many forests. If the forest of Stewart Island be excluded, the number of species rises to 232. The above figures, so far as they concern the Central botanical province are misleading, for the excess of species in that area above the total of the Northern province does not denote that a typical central lowland-forest contains more species than does one of the N. but rather that certain characteristic northern plants extend for a short distance into the Central province and that, in addition, there are a few species, generally quite local, confined to the latter. In fact there is a gradual decrease in forest-species in proceeding from N. to S., a happening suggestive of their northern origin. Nor does the southern total represent the true condition of affairs for 28 species are confined to the North-western and North-eastern districts.

The species decrease in number with increase of altitude, though others enter in which are wanting at a lower lovel. A montane northern forest differs considerably from that of the adjacent lowland and has a more southern facies. The lowland forests are rarely pure, so far as the taller trees are concerned, but there is a mixture of many species. The edaphic association where *Podocarpus dacrydioides* is the sole tall tree forms a striking exception.

b. Characteristics of the mixed rain-forest.

The mixed rain-forest associations possess so many features in common that, in order to avoid repetition, the following details are submitted.

The trees, shrubs and ferns, with a few trifling exceptions, are evergreen. Excepting in the Kauri forest, taxads dominate, so far as the tallest trees are concerned. As viewed from without, the evergreen character of the trees, and the general absence of bright greens, gives, when seen from a distance, a sombre aspect to the forest, while the density of their growth altogether masks the height of the trees. But a closer view reveals the varied greens and it is not difficult, in some instances, to recognize certain species from their colour alone, especially in low, even forests of dry ground. An outside view, too, reveals but little of the tropical character of the forest. A few tree-ferns may raise their crowns of spreading, feathery leaves above the greenery, or, in the N. or C., a nikau palm *(Rhopalostylis sapida)* peep forth, but that is all. But push through the belt of shrubs, or low trees, that may fringe its outskirts, and the vision within will be novel enough to one acquainted only with the temperate forests of the northern hemisphere.

Massive trunks, unbranched for many metres, meet the eye, some covered so thickly with lianes and epiphytes, many of which are ferns and bryophytes, that their bark is invisible. Open spaces are few, or wanting. Young trees, shrubs of many kinds and tree-ferns 5—10 m high, growing in clumps or isolated, closely fill the gaps between the tree-trunks. Rope-like liane-stems depend from the forest-roof swinging in the air, or lie sprawling upon the ground. The bases of the trees are not infrequently swollen and irregular, while their roots spread far and wide over the surface, at times half-buried, or, here and there, arching into the air, and covered with seedling trees and shrubs, ferns of goodly size, mantles of mosses and liverworts, lichens and sheets of pellucid *Hymenophyllaceae.* Fallen trees, in various stages of decay, lie everywhere, and these too, hidden by a garb of water-holding greenery are the home of seedlings innumerable. The actual forest-floor is most uneven; rotting logs, fallen branches, raised roots, ferns frequently with short trunks and bryophyte- or *Hymenophyllum*-covered mounds of humus make walking laborious. Progress is considerably retarded, too, not merely by the above obstacles, or by the close-growing shrubs or spreading branches, but by a coarse network of the almost black, stiff stems of the liliaceous liane, *Rhipogonum* *scandens*, forming entanglements beneath which one is compelled, at times, to crawl on hands and knees. In other places, the hooked prickles on the mid-ribs of *Rubus australis*, catching a garment, may hold one fast. Furthermore, even on level ground, there are water-courses, here and there, and near these the density of the undergrowth increases, lateral branches from the trees on either side meet and become entangled, the growth of ferns becomes thicker, so that progress is well nigh impossible. In hilly forest, the density of gullies is still more intensified.

The close growth, which I have attempted to describe, is in harmony with the moist, equable climate, but regulated by the density of the forest-roof. Everywhere the effect of that complex of factors, evoked by the forest itself, is manifest in the plant-forms. Shrubs, which in the open would be rounded and symmetrical, put forth long, slender stems, that, liane-like, lean against other trees and gain support. Young trees have frequently much-reduced lateral branches and long, straight, slender main-stems. In some this habit is hereditary, and thus the curious juvenile form of *Pseudopanax crassifolium* may be an "adaptation" to the forest-life.

On the trunks of most of the trees that do not shed their bark in great flakes and right up on the highest branches are not only an abundance of true lianes and epiphytes (Plate XXII, Fig. 29), but seedlings of trees and shrubs, terrestrial ferns of many species and hosts of mosses, liverworts and lichens. The trunks of tree-ferns, too, are a favourite station for many plants. Even the slender branches of shrubs may be deeply moss-covered, while leaves themselves may be the home of various small bryophytes.

Certain forests are not nearly so dense, or hygrophytic as described above, nor do they exhibit so fully the various peculiarities as cited, but such occupy dryer ground than usual, and even then show unmistakably their tropical facies.

In every type of New Zealand rain-forest the vegetation is in several distinct layers, each with a definite light-relation. Where the tallest trees are present, the uppermost layer consists of their crowns, especially those of the *Taxaceae*, or, in certain associations, *Metrosideros robusta*, one or other of the two species of *Weinmannia*, *Beilschmiedia tawa*, *B. tarairi*, or species of *Nothofagus*. Trees of a medium size form the next layer, while growing in their crowns, as also in those of the upper tier, are the flowering parts of the lianes and the more massive epiphytes (e. g. — species of *Astelia*, *Griselinia lucida*, *Pittosporum cornifolium*, young *Metrosideros robusta*). The upper tier does not, as a rule, make a continuous roof, so the light-relation of these two highest tiers is not very different. The third layer is formed by the smaller trees, tallest shrubs and tall tree-ferns, while, in the N. C. and northern part of the South province the nikau palm is conspicuous. Next comes the fourth layer, consisting of the smaller ferns, prostrate or low shrubs, decumbent lianes, tussocks of *Gahnia* or *Astelia* and young plants of various kinds. Finally, there is the layer of actual floor-plants, which are mostly bryophytes, creeping herbs including ferns, and seedlings of many kinds.

c. *Kauri* (*Agathis australis*) *forest.*

1. General.

The name "kauri" is given to this association not because that tree is dominant, for this is rarely the case, but on account of its striking character and its being always accompanied by a special group of plants (Plate XXIII, XXIV, Fig. 30, 31). According as the kauri or some other tree is dominant, especially *Beilschmiedia tarairi* or *B. tawa*, so may the association be divided into subassociations.

The number of species of kauri-forest is about 230 (pteridophytes 64, spermophytes 166) belonging to 54 families and 117 genera. The growth-forms are: — Trees 61, shrubs 38, herbs (most quite unimportant) 23, grass-like plants 12, lianes (excluding ferns) 20, epiphytes (excluding ferns) 13, parasites 2 and ferns 61. There are many species of *Hepaticae* and *Musci* forming colonies, mats or patches on the ground and fallen logs or draping tree-trunks, but they are not so luxuriant, or abundant, as in the forests of the W. and S. of the South Island. The most important genera of these plants are: — (*Hepaticae*) *Aneura*, *Symphyogyna*, *Monoclea*, *Treubia*, *Chiloscyphus*, *Frullania*, *Mastigobryum*, *Lepidozia*, *Schistochila*, *Trichocolea*, *Plagiochila*, *Tylimanthus*, *Madotheca*; (*Musci*) *Leucoloma*, *Dicranoloma*, *Leucobryum*, *Leptostomum*, *Hymenodon*, *Bryum*, *Echinodium*, *Ptychomnion*, *Weymouthia*, *Mniodendron*, *Sciadocladus*, *Lembophyllum*, *Distichophyllum*, *Hypopterygium*, *Cyathophorum*, *Rhacopilum*, *Mniadelphus*.

The forest-area, before the interference of man [1]) extended from a line joining Doubtless and Ahipara Bays in the N. to the Auckland Isthmus in the S. together with the Barrier Islands and the lower slopes of the Thames Mountains. Kauri-forest is essentially an association of the lowlands and lower hills and generally does not ascend to much over 400 m. Nor can it tolerate wet ground, so that its abundant remains in lowland bogs indicates change of level in the land-surface (Cf. CHEESEMAN 1897a: 344).

As seen from without, the branching crowns of *Agathis* towering above the general level of the roof, itself the crowns of tall trees, gives the impression of one forest superimposed on another (Plate XXV, Fig. 32). The dark-green foliage of *Metrosideros robusta* also stands out here and there. Near the outskirts of the forest-mass there may be lines or groves of young kauris conspicuous through their pyramidal form.

2. Northern kauri-forest.

This consists of two sub-associations, — the Kauri and the Taraire, the latter generally forming the bulk of the forest.

Taraire sub-association (Plate XXIV, Fig. 31).

Beilschmiedia tarairi is dominant, the trees some 15 m high, 3 m or so apart, straight, upright, 30—60 cm in diam. and the crown small but dense.

1) The forest is enormously reduced through saw-milling and fire and, except where reserved, will be absolutely gone in a dozen years from now. Extensive as these primitive kauri-forests

Generally the roof is fairly open. *Metrosideros robusta* is common and conspicuous through its most irregular trunk full of hollows filled with humus supporting so many bryophytes, filmy ferns, herbaceous ferns and shrubs that its brownish, furrowed bark is hidden by the wealth of greenery[1]). Frequently, the trunk leans out of the perpendicular in which case it will support a dense growth of immense asteliads right to the forks of its great twisted branches in the forest-roof. Other common trees are: — *Podocarpus totara*, *P. ferrugineus*, *Dacrydium cupressinum*, *Phyllocladus trichomanoides*, *Knightia excelsa*, *Dysoxylum spectabile*, *Beilschmiedia tawa* and *Weinmannia sylvicola*. Much rarer, and not in all localities, are: — *Libocedrus Doniana*, *Dacrydium Kirkii*, *D. Colensoi* and *Phyllocladus glaucus*.

The undergrowth, in many places, is not dense, but it varies greatly in this regard according to the intensity of the light. In many parts, it consists of a more or less thick growth of the following young forest-trees, low trees, shrubs and tree-ferns: — *Knightia*, *Dysoxylum*, *Beilschmiedia tarairi* (these three with long, straight main-stem and few lateral branches), *Drimys axillaris*, *Pittosporum tenuifolium*, *Melicytus macrophyllus*, *Myrtus bullata*, *Nothopanax arboreum*, *Pseudopanax crassifolium*, *Rapanea Urvillei*, *R. salicina*, *Geniostoma ligustrifolium*, *Coprosma grandifolia*, *C. arborea* (in dry ground), *Alseuosmia macrophylla*, *Olearia Cunninghamii*, *Cyathea medullaris*, and *C. dealbata*. In other parts, there is a thicket of tussocks of *Gahnia xanthocarpa*, *G. setifolia*, and *Astelia trinervia* mixed with entangled stems of *Rhipogonum scandens* and *Freycinetia Banksii*.

The palm, *Rhopalostylis sapida* is often abundant, its growth-form rendering it specially conspicuous. Tree-trunks are draped thickly by climbing species of *Metrosideros* or the fern *Blechnum filiforme*; shrubs and slender trees are festooned and bound together by the twining leaf-spindles of *Lygodium articulatum*; on horizontal branches are masses of *Astelia Solandri* and long tassels of *Lycopodium Billardieri* swing in the air. *Asplenium flaccidum*, *A. adiantiforme*, *Dendrobium Cunninghamii*, *Pittosporum cornifolium* and *P. Kirkii* are also common epiphytes.

Open spaces of the forest-floor are occupied by mats of vivid green *Hymenophyllum demissum*, *Freycinetia*, juvenile *Blechnum filiforme*, rooting *Metrosideros hypericifolia*, seedlings of trees and shrubs and various bryophytes. Fallen trees are thickly covered with translucent *Hymenophyllum dilatatum*, its fronds 30 cm long and *Trichomanes reniforme* dark-green when old, but emerald when young.

In moist gullies, the vegetation changes. *Beilschmiedia tarairi* is rare or absent and *Laurelia novae-zelandiae* the common tree; the palm, generally trunkless, may be so abundant as to dominate. The following are character-

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were, they were only the remains or successors of previous ones, the site of which is marked by the abundance of kauri-resin, or in places tree-trunks, beneath the surface of the ground.

1) This description applies to this tree, not only in kauri-forest but in forest generally.

istic: — *Dicksonia squarrosa* (tree-fern), *Dryopteris pennigera* (here with a trunk), *Asplenium bulbiferum*, mats of *Hymenophyllum demissum*, *Rhipogonum*, *Elatostema rugosum* (the succulent stems with their bronzy leaves raised 1 m above the ground and occupying many square metres), creeping juvenile *Rubus schmidelioides* and the shrub *Schefflera digitata*. On shaded banks of streams is *Trichomanes rigidum*, its dark fronds covered with small epiphytic mosses.

Kauri sub-association.

This plant-community is well-marked and uniform in composition. Besides *Agathis australis* the following are generally present: — *Cyathea dealbata*, *Dicksonia lanata* (often extremely common), *Blechnum Fraseri*, *Gahnia xanthocarpa*, *Astelia trinervia*, *Freycinetia Banksii*, *Fusanus salicifolia*, *Weinmannia sylvicola* (juvenile), *Phebalium nudum*, *Dysoxylum spectabile* (juvenile), *Metrosideros florida*, *M. albiflora*, *Nothopanax arboreum*, *Dracophyllum latifolium*, *Styphelia fasciculata*, *Geniostoma ligustrifolium*, *Coprosma grandifolia*, *Alseuosmia macrophylla* and *Senecio Kirkii*.

The sub-association owes its very characteristic physiognomy partly to the dense tussock-thickets of *Gahnia-Astelia* and partly to the form of the kauri itself. Where it extends over a wide area, the undergrowth is not thick. The kauri-trunks, usually shining-grey, but sometimes reddish, rise up on all sides, as far as the eye can pierce, as massive columns 1—3 m in diam., unbranched for 20 m or more (Plate XXVI, Fig. 33). Round the base of each tree is a mound of humus, formed from the shed bark, occupied by small tussocks of *Astelia trinervia*, sprawling *Metrosideros florida* and *Senecio Kirkii*. Rising up between the giant trunks may be multitudes of the straight stems of *B. tarairi*, thrusting their sparse heads of foliage up to the lower branches of the kauris, or *B. tawa* with its irregular thicker trunk, bryophyte-covered, may be abundant. Between the trees, there will be a rather low, open undergrowth consisting of (the first three species being dominant): *Cyathea dealbata* (trunks 1 m or less), *Dicksonia lanata* (25 cm high, in colonies, the green fronds arching outwards, their blackish stems shining with a metallic lustre), juvenile *Weinmannia silvicola* with yellowish-green pinnate leaves, black-stemmed *Drimys axillaris*, slender *Dysoxylum*, graceful young *Beilschmiedia tawa*, *Melicytus macrophyllus*, *Rapanea salicina*, *Coprosma grandifolia*, stemless *Rhopalostylis*, *Alseuosmia macrophylla*, *A. quercifolia*, *A. Banksii*, *A. linariifolia* and juvenile *Podocarpus ferrugineus*. On the ground will be: — trailing *Freycinetia*, straggling *Lygodium* (also winding round the young trees), extensive colonies of *Blechnum Fraseri*, and in some localities the low straggling shrub *Pittosporum pimeleoides* and the curious fern *Schizaea dichotoma*. High above all rise up the mighty spreading limbs of the kauris and extending to these the lace-like foliage of *Beilschmiedia tawa* or the darker, denser heads of *B. tarairi*. Lianes are not numerous, an occasional *Freycinetia* or *Lygodium* ascend the *Beilschmiedia* trees, but the kauri itself, owing to its bark-shedding habit, remains inviolate.

Much more common than such extensive kauri-communities are groves, large or small, scattered through the forest-mass. The kauri trees are generally 20 m or more distant and the intervening space is occupied by an extremely thick *Gahnia-Astelia* thicket containing also — *Freycinetia*, *Metrosideros florida*, *M. albiflora*, *Phebalium nudum*, *Senecio Kirkii* and all the other species already cited as prominent members of the sub-association. Obviously these shrubs &c. are wanting where the *Gahnia-Astelia* is densest.

3. Southern kauri-forest.

The kauri-forests on the E. of Auckland and S. of Kaipara Harbour, on the W., are almost eradicated though areas more or less damaged still exist and are, in places, slowly regenerating. Thanks to an early paper of CHEESEMAN's (1872: 270), it is possible to give some account of the original vast forest on the Waitakerei Hills, since he examined a portion before it had been seriously interfered with.

The dominant tree was *Beilschmiedia tawa* which, "probably formed three-fifths of the forest". The other most abundant trees were: — *Agathis*, *Dacrydium cupressinum*, *Elaeocarpus dentatus*, *Knightia*, *Litsaea calicaris*, *Metrosideros robusta*, *Pittosporum tenuifolium* and *Rapanea Urvillei*. The undergrowth was dense and consisted of: — *Alseuosmia macrophylla* (abundant), species of *Gahnia*, *Astelia* and *Coprosma*, *Rhipogonum*, *Myrtus bullata* and *Senecio Kirkii*; *Hymenophyllaceae*, ferns in general and bryophytes were very plentiful.

The originally extensive forests of the Thames sub-district, except on the Little Barrier Island, Mount Te Aroha and a few other localities, are altogether gone or much modified. Some light is thrown on the original plant-covering by the writings of T. KIRK (1870a: 89) and J. ADAMS (1884: 385; 1889: 32). Without going into details, the forest was much as already described, but *Beilschmiedia tarairi* and *Dicksonia lanata* were scarce.

4. Transition between forest and heath.

Between kauri-forest and gumlands' heath there is frequently intercalated a low tree-association where heath-and forest-plants intermingle, that may be considered the first stage in the evolution of kauri-forest. Its most common members are: — *Cyathea dealbata*, *Knightia excelsa*, *Persoonia toru*, *Weinmannia sylvicola*, *Leptospermum ericoides*, *L. scoparium*, *Pseudopanax crassifolium*, *Styphelia fasciculata*, *Olearia Cunninghamii* and *Senecio Kirkii*. Some young kauris will also be present, indeed stunted examples appear on the heath itself. Common undergrowth plants are: — *Blechnum Fraseri*, *Lycopodium densum*, *L. volubile*, *Gahnia xanthocarpa*, *Astelia trinervia* and *Geniostoma*.

5. Rejuvenation.

Everywhere a kauri-forest is in a state either of progression or retrogression. For instance, one area may possess many large trees but little undergrowth while another area may have a powerful undergrowth which, in time, through survival of the fittest, and the inability of juvenile trees to produce seed, turns into a close forest with little undergrowth. The above are two opposite stages, each a distinct expression of the light-factor, the dense undergrowth marking a maximum and the close forest-roof a minimum. With increased illumination, hygrophytes are replaced by xerophytes, so that, with an ever-increasing light-intensity, forest will be replaced by heath. Or the opposite may take place and heath be the first of a series culminating in pure kauri-forest.

The pioneer forest-trees are probably the species of *Leptospermum*, *Knightia*, *Weinmannia sylvicola*, *Pseudopanax crassifolium* and *Persoonia*. Then would come *Agathis* and *Podocarpus totara*, and, later on, the species of *Beilschmiedia*. The kauri sub-association would thus antedate that of *Beilschmiedia*. With a constant climate, the forest would slowly change and reach its climax; then, the old trees dying, the light-intensity would increase, seedlings could grow and rejuvenation gradually come about. But should the climate become dryer heath-conditions would rule.

d. Taxad-forest.

1. General.

The forest, here considered, is that in which species of *Dacrydium* or *Podocarpus* either dominate or play a conspicuous part. There are two distinct classes of associations, those of dry and those of semi-swampy ground, but not only are they connected by intermediate combinations and floristically very similar, but they contain the same growth-forms and can hardly be considered ecologically distinct. All the same, the difference in habitat makes itself strongly felt, insomuch that the forest of the dryer ground is a mixed community with several tall trees dominant, or subdominant, whereas the semi-swamp forest is pure so far as tall trees are concerned.

Taxad-forest occurs throughout the North, South and Stewart Islands, originally occupying wide areas in all the botanical districts, except where a steppe-climate forbade, nor is it restricted to the lowlands.

If the species almost confined to other forest-associations be omitted together with those of great rarity, but counting those restricted to some botanical district, or portion of such, then the total number of species for the whole taxad-forest of New Zealand is about 300, of which 71 are trees, 52 shrubs, 24 lianes (excluding ferns), 12 epiphytes, 5 parasites, 43 herbs (few of any moment), 23 grasslike plants and 70 ferns. Bryophytes and lichens are extremely numerous and, the former especially, are often of physiognomic importance.

Taxad-forest falls naturally into the two classes non-swampy and swampy, each of which includes, as seen further on, several associations distinguished by the dominance of some particular tree. The nature of the underlying rock seems of little moment, but New Zealand plant-formations in general have not been sufficiently investigated in this regard.

As for the kauri-forest, so with the taxad, there is no true stability. Insufficient studies have been made to allow statements of any degree of certanity, but it is evident that some of the associations are more hygrophytic than others, while, where the struggle for existence has been observed in action, one tree or association can be seen replacing another. Leaving *Nothofagus*-forest out of consideration, perhaps *Dacrydium cupressinum*- and *Podocarpus totara*-forest are the most primitive, the one in the wettest and the other in the dryest forest-climate. But whatever totara-forest may be, *D. cupressinum*-forest cannot be considered a climax-association, since in the N. and C. it is being replaced by *Weinmannia sylvicola*, *Metrosideros robusta* and *Beilschmiedia tawa* and, in the S.[1]), possibly by *Weinmannia racemosa* in some places and by *Metrosideros lucida* in others.

2. Rimu (Dacrydium cupressinum) forest.

General.

This association extends from the high land S. of Hokianga Harbour to Stewart Island. In the Northern botanical province it does not occur at a much lower altitude than 600 m, while in the Volcanic Plateau and East Cape botanical districts, it is frequently an upland forest.

The association is defined by the presence of *Dacrydium cupressinum* as the dominant but not the sole tall tree, *Podocarpus ferrugineus*, *P. spicatus*, *P. totara*, *P. Hallii*, *P. dacrydioides* (Plate XXVII, Fig. 34) and one or other of the species of *Weinmannia* frequently being present.

The physiognomy of the association needs no special description since that already given for New Zealand rain-forest applies in every particular. The rimu itself always stamps the association, its rather small yellowish-green heads of drooping shoots distinguishing it from any other tree.

The floristic character of the forest changes greatly in passing from N. to S. and there are various combinations of species depending upon latitudinal change. These types may be considered sub-associations but all are connected by intermediates and the whole formed originally a gradually-changing, more or less connected forest-mass extending from the N. to the S. of New Zealand. The change is entirely floristic and is brought about by the gradual decrease in northern forms, in passing southwards, and the increase in individuals of species common to the whole area, plus the admission of a few members absent in N. Auckland and restricted to the mountains in most of the Central province. Apart from the effect of change in latitude, change in altitude and soil plays an important part, so that there is no true uniformity in any forest-area, nor does any description disclose the actual relations of the species. Below a brief description is given of the forest of specified areas so that a general idea may be gained of the association as a whole, but no attempt is made at a definite classification of the different sub-associations.

On Plateau south of Hokianga Harbour at 600 m *altitude.*

The tall trees vary from 15—30 m in height. Besides the dominant rimu there are also, — *Podocarpus ferrugineus*, *P. Hallii* (occasional), *Beilschmiedia*

1) Also in the upland forest of the Central province.

tawa and *Weinmannia sylvicola.* The undergrowth consists principally of, — *Dicksonia squarrosa*, *D. lanata*, *Hemitelia Smithii*, young *W. sylvicola*, *Ixerba brexioides*, *Nothopanax Edgerleyi*, *Schefflera digitata*, *Griselinia littoralis*, *Coprosma grandifolia* and *Senecio Kirkii.* This undergrowth is so tall, that were the larger trees removed, it would still rank as forest. On the forest-floor, liverworts and mosses luxuriate, together with great quantities of *Hymenophyllum ferrugineum*, *Trichomanes elongatum* and *Blechnum nigrum*. *Freycinetia* (liane) and epiphytic asteliads are fairly common.

Volcanic plateau (Mamaku) near Rotorua.

Rimu and *Beilschmiedia tawa* are dominant. The other tall trees are: — *Knightia*, *Weinmannia racemosa*, *Elaeocarpus dentatus* and *Metrosideros robusta*. The shrubby undergrowth includes: — *Ixerba*, *Melicytus ramiflorus*, *Nothopanax arboreum*, *N. Edgerleyi*, *Schefflera*, *Griselinia littoralis* and *Alseuosmia macrophylla*. *Hymenophyllaceae* including *T. reniforme* and bryophytes are plentiful. *Rhipogonum* is the principal liane[1]).

Lake Waikaremoana (E. Cape district) at 600 m *altitude.*

The principal tall trees are the rimu, *Podocarpus ferrugineus*, *Elaeocarpus dentatus*, *Weinmannia racemosa* and an occasional *Nothofagus fusca*. Some of the shrubs &c. of the undergrowth are: — *Dicksonia squarrosa*, *Cyathea dealbata*, *Hemitelia Smithii*, *Drimys colorata*, *D. axillaris*, *Carpodetus serratus*, *Weinmannia*, *Pittosporum tenuifolium*, *Melicytus ramiflorus*, *Fuchsia excorticata*, *Nothopanax arboreum*, *Coprosma grandifolia*, *C. tenuifolia*, *C. foetidissima* and *Brachyglottis repanda*.

Waimarino forest near Ohakune.

The rimu is abundant and of great size. Other tall trees are: — *Podocarpus ferrugineus*, *P. spicatus*, *Weinmannia racemosa*, *Olea Cunninghamii*, *Metrosideros robusta* and *Beilschmiedia tawa*. The undergrowth includes: — *Drimys colorata*, *D. axillaris*, *Melicytus ramiflorus*, *Myrtus pedunculata*, *Fuchsia excorticata*, *Rapanea salicina*, *Nothopanax arboreum*, *Coprosma tenuifolia*, *C. grandifolia* and *Alseuosmia quercifolia*. *Leptopteris superba* is abundant.

Mount Egmont (Taranaki).

The forest is of great age. Everywhere *D. cupressinum* is being killed and replaced by *Metrosideros robusta*. The other tall trees are *Weinmannia racemosa*, *Knightia excelsa* and *Beilschmiedia tawa*. The undergrowth contains victually all the forest-shrubs &c. of the Central botanical province. Epiphytic *Senecio Kirkii* is very abundant, as also the asteliads.

Westland coastal plain.

Westland rimu forest is distinguished from those noted above by the presence in large quantities of *Ascarina lucida* and *Quintinia acutifolia*[2]).

1) In all these lists, for sake of brevity many species have to be omitted.

2) *Quintinia acutifolia* is a small, rather fastigiate tree of slender habit with abundant leaves of oblong type 7.5—12 cm long, yellowish with green veins and midrib.

Ascarina lucida is a low, bushy-tree with almost black bark and green, extremely glossy, oblong serrate leaves 2.5—5 cm long.

Weinmannia racemosa may equal the rimu in abundance. Other important shrubs &c. of the undergrowth are: — small *P. ferrugineus*, *Carpodetus*, juvenile *Elaeocarpus Hookerianus*, juvenile *Pseudopanax crassifolium* and *Schefflera*. From taxad-forest of the eastern and southern parts of the South Island and from that of Stewart Island the association is distinguished by the abundance of the lianes *Freycinetia* and *Metrosideros florida* and the epiphyte *Astelia Cunninghamii* and by the absence of *Pittosporum eugenioides* and *P. tenuifolium*. Bryophytes, though not building cushions, are abundant enough to be of prime physiognomic importance, especially *Weymouthia mollis* and the larger *W. Billardieri* hanging from slender branches or twigs and, on the forest-floor, *Plagiochila gigantea* and other species of the genus, extensive mats of the pale-green *Trichocolea tomentella* frequently glistening with drops of water and species of *Schistochila*.

South Otago and Stewart Island districts (Plate XV, Fig. 20).

The *Dacrydium-Weinmannia* forests of these two districts have so much in common that one description will suffice for both. Generally some *Metrosideros lucida* is present and, at times, in such abundance that it equals the two other trees.

The dominant shrub of the undergrowth is *Coprosma foetidissima*, and *C. Colensoi* and *C. Banksii* are common. *Rhipogonum* is the only important liane. Asteliads, as epiphytes are absent but *Dendrobium Cunninghamii* is still plentiful and *Griselinia littoralis* replaces its epiphytic relative of the N. *Hemitelia* is the prevalent tree-fern, and, as ground-ferns *Blechnum discolor*, *B. capense* and, at times *Leptopteris superba* make extensive colonies. In the N. of the South Otago botanical district *Weinmannia* was virtually absent in the originally extensive forest-area. *Pittosporum tenuifolium*, *P. eugenioides* and *Nothopanax arboreum* are absent in Stewart Island, the place of the first-named being filled by *P. Colensoi* var. *fasciculatum* and of the last by *N. Colensoi*.

3. Totara (Podocarpus totara or P. Hallii) forest.

Totara-forest is taxad-forest in which either *P. totara* or *P. Hallii*, or both, are dominant. The association is more xerophytic than that of *Dacrydium cupressinum*, the tree being able to occupy dry ground or exposed positions where the latter would perish[1]). At the same time, it must be pointed out that totara to a varying extent is nearly always present in rimu-forest and may equal the rimu in importance in which case there would be a rimu-totara association.

At the present time, it is not possible to state accurately the distribution of the association. CAMPBELL-WALKER (1877) in his account of forest-distribution

1) *D. cupressinum* can be grown only in sheltered, shady positions whereas *P. totara* can be easily cultivated in ordinary garden conditions without any special care, and but for its relatively slow growth would be suited for afforestation purposes.

in New Zealand defined a "central or totara district", which included all the forest-lands of the East Cape, Volcanic Plateau and Wellington portion of the Ruahine-Cook botanical districts. Now although his area as a whole certainly contained abundant totara, yet there are also rimu, kahikatea and other forest-associations and it is probable that the actual totara-forests were limited, as now, to the Volcanic Plateau from the N. and W. of lake Taupo to the main-trunk line. Elsewhere there were most likely rimu-totara and rimu-totara-matai associations. In the South Island totara-forest appears to have been almost restricted to the Eastern district, although the species is of wide distribution and certainly occurred in considerable quantities in all the districts, except North Otago, while in the Western *P. Hallii* is the dominant species of the lower subalpine forest.

At one time, totara forest was much more wide-spread in the Eastern and North Otago districts than is now the case, but how long ago this was who can say? All we know is that totara logs lay on the ground in abundance in Central Otago and parts of Canterbury now treeless. There is no clue as to what caused the destruction of these ancient forests. The story goes that there was a vast forest-fire in pre-European days, but it is hard to see how such could cause the wholesale and absolute destruction or why the fallen logs remained. Still more remarkable is the fact of a forest, still undestroyed, marking the limit of the western rainfall. The climate too, where those tree-remains lie, is distinctly too dry for the natural occupation by totara forest and I can only conclude with SPEIGHT (1911: 417) that the forest came into existence during a much wetter period than the present. This would also account for the rarity of *Dacrydium cupressinum* on Banks Peninsula, the wet climate favouring its establishment, but with increasing dryness the totara and other more xerophytic plants made headway, eventually replacing the rimu. But there still linger on Banks Peninsula a few examples of *Nothofagus*, which may be considered a remnant of a forest, earlier than the rimu, established during the ancient steppe-climate of Canterbury referred to further on (Part IV). This, during the wet period which favoured the establishment of the almost vanished totara association of Otago-Canterbury, would be gradually replaced in the still wetter climate of Banks Peninsula by the rimu. Nor does the occurrence of *Podocarpus spicatus* in abundance on Banks Peninsula along with totara offer rebutting evidence. On the contrary that species is distinctly xerophytic in its remarkable juvenile form and tolerates less hygrophytic conditions than *D. cupressinum*.

Wherever totara forest is situated, its composition is similar to that of other adjacent rain-forest associations. A brief description of the association at an altitude of some 300 m near Taumaranui will give some idea of the forest as it occurs in the most extensive area of its distribution.

The soil is pumice mixed near the surface with a good deal of humus. Besides the dominant *P. totara* there is a great deal of *P. spicatus*. The taxads form the upper tier of foliage; their straight, columnar trunks are a striking feature, those of *P. totara* bearing but a scanty covering of bryophytes, its outer bark hanging in long strips. Some of the other forest-trees are: — *Knightia excelsa*, *Beilschmiedia tawa* (abundant), *Carpodetus serratus*, *Weinmannia racemosa*, *Pennantia corymbosa*, *Alectryon excelsum*, *Hoheria sexstylosa*, *Melicytus ramiflorus*, *Fuchsia excorticata*, *Nothopanax arboreum*, *Rapanea Urvillei*, *Olea montana* and *Brachyglottis repanda*. Most of the above also occur as shrubs or young trees of undergrowth in which likewise, amongst others, the following occur: — *Paratrophis microphyllus* (very common), *Aristotelia racemosa*, *Myrtus pedunculata*, *Schefflera digitata* (dominant in some places), *Coprosma rotundifolia* and *Rhabdothamnus Solandri*. In some gullies of this particular community are hundreds of young plants of *Schefflera* 30 cm or so high, associated with various ground-ferns especially *Dryopteris pennigera*. The chief tree-fern, liane and epiphyte respectively are: — *Cyathea dealbata*, *Metrosideros hypericifolia* and *Astelia Solandri*. Bryophytes and *Hymenophyllaceae* are plentiful.

Forest of Banks Peninsula.

Banks Peninsula was originally covered with a forest in which *P. totara* and, in places, *P. spicatus* were dominant, except on certain northern slopes and at the summits of the higher peaks. In the deeper gullies where there were permanent streams was a wealth of ferns including *Hymenophyllaceae*, but according to ARMSTRONG's list (1880: 346), and to recent observations, only 2 or 3 species of these latter were at all plentiful. On many slopes and in the waterless stony gullies, the forest was of a dry character, as evidenced by the abundance of the ferns *Pellaea rotundifolia* and *Polystichum Richardi*. Certain negative features help to define the forest as a whole. Thus the following, some of which extend much further to the S. in the W. of the island, were absent: — *Trichomanes reniforme*, *Lindsaya cuneata*, *Freycinetia Banksii*, *Astelia Cunninghamii*, *Ascarina lucida*, *Weinmannia racemosa*, *Metrosideros lucida*, *M. florida*, *Nothopanax Edgerleyi*, *Rapanea salicina*, and *Coprosma grandifolia* while *Rhopalostylis*, though present in a few places, was generally wanting. On the other hand, the elsewhere rare liane *Senecio sciadophilus* is still abundant, *Tetrapathaea australis* is not uncommon, the rare *Teucridium parvifolium* is plentiful, the semi-liane *Microlaena polynoda* is fairly frequent and the shrubby nettle *Urtica ferox* occurs in many places. The following are common throughout[1]): — *Cyathea dealbata*, *Dicksonia squarrosa*, *Paratrophis microphylla*, *Clematis foetida*, *C. indivisa*, *Drimys colorata*, *Carpodetus*, *Pittosporum tenuifolium*, *Rubus cissoides*, *Melicope simplex*, *Pennantia corymbosa*, *Hoheria angustifolia*, *Plagianthus betulinus*, *Melicytus ramiflorus*, *Myrtus obcordata*, *Metrosideros hypericifolia*, *Fuchsia excorticata*, *F. Colensoi*, *Nothopanax arboreum*, *Griselinia littoralis*, *Rapanea Urvillei*, *Parsonsia heterophylla*, *P. capsularis var. rosea*[2]), *Calystegia tuguriorum*, *Coprosma robusta*, *C. rotundi-*

1) No attempt at completeness is aimed at, chiefly the physiognomic aspect is kept in mind.
2) I am not sure that this is not confined to Banks Peninsula.

folia, *C. areolata*, *C. rhamnoides*, *C. crassifolia*, *C. linariifolia*, *Helichrysum glomeratum* and *Olearia Forsteri*. *Sophora microphylla* and *Leptospermum ericoides* are still plentiful, especially on the open hillsides, but what part they played in the original forest I do not know.

Various isolated forest-areas in Canterbury (Plate XVIII, Fig. 24).

Comparatively small forest-areas with *P. totara* and *P. spicatus* dominant still persist in various sheltered spots on the foot-hills abutting on the Canterbury Plain extending from the base of Mount Peel to Waimate. No special description of these is needed, the species being much the same as on Banks Peninsula, but *Rhopalostylis*, *Macropiper excelsum*, and certain ferns are wanting.

4. Matai (Podocarpus spicatus) forest.

From what has gone before it can be seen that *P. spicatus* is frequently so common in totara-forest that it is sub-dominant at least but, on the other hand, it is rare or absent in many taxad-forests and, even when the principal tree for a time, it hardly forms more than a society. Such societies still remain on certain parts of the Southland Plain, the trees close together, rather stunted and their crowns more spreading than usual.

According to ROBERTS (Forestry in New Zealand, 1909: 52), *P. spicatus* forms small societies on the flats of nearly all the Westland rivers as far S. as the Cascade River. He also mentions stunted trees, 2.4 m in diam. with "short bunched trunks dividing into several long, heavy branches".

As already-noted *P. spicatus* is now extremely rare in Stewart Island, but the remains of trees, probably 300 to 400 years dead, lie abundantly upon the forest-floor, but frequently embraced by the trunk, originally root, of a mature *Weinmannia racemosa* (Plate XVII, Fig. 22).

5. Tawa (Beilschmiedia tawa) association.

Although taxads may be absent, this association is classed with taxad-forest, since it may contain all the other members of that class and is merely one of its phases of succession. The association occurs throughout the Northern and Central botanical provinces and is perhaps the most extensive of all the forms of taxad-forest. In most parts of the Egmont-Wanganui district it forms the bulk of the lowland-lower mountain forest and is one of the characteristic features of that botanical district.

Tawa-forest may, I think, be considered the final stage in the series of succession forming taxad-forest, that is to say, that wherever it occurs, one may conclude that forest rich in taxads previously occupied the ground. In support of this view, all degrees of intermediate stages exist between rimu- and tawa-forest. On the Wanganui coastal-plain, where tawa-forest is dominant, the ridges are invariably occupied by the altogether different formation of *Nothofagus Solanderi*, already referred to, the significance of which is discussed in Part. IV.

The physiognomy of the association, as a whole, is determined by the dominance of *B. tawa*, a most graceful tree with willow-like foliage, already described in Chapter II of this section. Within, the association both floristically and ecologically resembles that of *Dacrydium cupressinum*, the species of course varying according to latitude. Young *B. tawa* is abundant and the forest will reproduce its like under uniform climatic conditions.

6. Puriri (Vitex lucens) association.

This well-marked association was evidently once common on volcanic soil in the North Auckland botanical district, but the value of the puriri for fencing posts &c. has led to a great reduction in its area. *Vitex lucens* itself is a most handsome tree, 12—18 m high with a massive, frequently irregular trunk and much-spreading rounded crown with large digitate leaves on petioles some 10 cm long and 3—5 dark-green, smooth, glossy, oblong leaflets, the largest measuring 7.5 cm long, or more. Besides *Vitex* the following were common members of the association: — *Podocarpus totara*, *Beilschmiedia tarairi*, *Dysoxylum spectabile* and *Melicytus ramiflorus*. Asteliads were in abundance on the puriri [1]).

7. Small tree-communities near banks of rivers.

Here associations on deep alluvial soil are alone noted, those of stony river-bed being dealt with further on under another heading. The associations often form a fringe along the bank which may or may not be connected with an adjacent forest-mass.

The following are the principal species of the above habitat: — *Cordyline australis*, *Muehlenbeckia australis*, *Carpodetus serratus*, *Pittosporum Colensoi*, *P. Ralphii*, *Rubus schmidelioides* var. *coloratus*, *R. subpauperatus*, *Sophora tetraptera*, *S. grandiflora*, *S. microphylla*, *Melicope simplex*, *Coriaria ruscifolia*, *Pennantia corymbosa*, *Aristotelia racemosa*, *Hoheria populnea*, *H. sexstylosa*, *H. angustifolia*, *Plagianthus betulinus*, *Hymenanthera dentata* var. *angustifolia*, *Melicytus micranthus*, *Leptospermum scoparium*, *L. ericoides*, *Fuchsia excorticata*, *F. Colensoi*, *Nothopanax anomalum*, *Parsonsia heterophylla*, *Veronica salicifolia*, *Coprosma rotundifolia*, *Olearia Hectori* and *O. fragrantissima*.

The species of *Hoheria* and *Sophora* according to their distribution and *Plagianthus betulinus* are specially characteristic. In the East Cape District, *S. grandiflora* (little more than a shrub), *Pittosporum Ralphii* and *Hoheria sexstylosa* are companion-plants. *H. dentata* var. *angustifolia* is characteristic of river-bank association on the Southland Plain and *O. Hectori* may also occur. Other low forest trees and shrubs frequently form an important part of the vegetation, e. g. *Ackama rosaefolia* (in the far N.), *Pittosporum tenuifolium* and *Nothopanax arboreum*. The river-bed forest of the Western district, described further on under another head, is a closely-related association, but one with a quite different life-history.

1) I have only seen much-reduced and damaged examples of the association and can supply no precise details.

8. Semi-swamp Forest.

In New Zealand, where there are extensive plains traversed by rivers rising in glacial mountains, floods must frequently occur, the water from which, in an undrained land, would but slowly recede, while some, gaining hollows, would remain permanent, forming shallow lakes or swamps. Not infrequently, too, low-lying forest would be flooded, so that new conditions would arise for the plants and those naturally possessing extra water-tolerating capacity would survive in the struggle for existence. In such areas, liable to flood, the sluggish streams would be readily blocked by forest-débris and forest permanently wet be established. In time, certain species should become specially attuned to the semi-swamp life and new forms be evolved. The composition of a New Zealand semi-swamp forest supports the above statements, since there are two classes of species, the one consisting of quite facultative swamp-plants which also inhabit dry ground and another class which if not true obligates are almost altogether confined to situations subject to submergence either permanent or for long periods. Then there comes a third class which are not characteristic of such forests, but which occasionally occur, though probably only in the dryer ground. The following is a list of the species, taking the habitat throughout New Zealand, which belong to the first two classes: — (Semi-obligate) *Lycopodium ramulosum*, *Laurelia novae-zelandiae*, *Rubus schmidelioides* (juvenile form), *Eugenia maire*, *Coprosma tenuicaulis*, *C. rigida*; (facultative) *Dicksonia squarrosa*, *Blechnum capense*, *Asplenium bulbiferum*, *Dryopteris pennigera*, *Gleichenia Cunninghamii*, *Podocarpus Hallii*, *P. nivalis*, *P. dacrydioides*, *Dacrydium intermedium*, *D. Colensoi*, *Phyllocladus alpinus*, *Freycinetia Banksii*, *Microlaena avenacea*, *Gahnia setifolia*, *G. rigida*, *G. xanthocarpa*, *G. procera*, *Rhipogonum scandens*, *Astelia nervosa*, *Rhopalostylis sapida*, *Paratrophis microphylla*, *Elatostema rugosum*, *Muehlenbeckia complexa*, *Drimys colorata*, *Carpodetus serratus*, *Melicytus micranthus*, *Leptospermum scoparium*, *Myrtus pedunculata*, *Schefflera digitata*, *Nothopanax anomalum*, *Pseudopanax crassifolium*, *Geniostoma ligustrifolium*, *Coprosma rotundifolia*.

α. Kahikatea (Podocarpus dacrydioides) forest.

Kahikatea forest occurs throughout New Zealand with the exception of the North Otago and Stewart districts in the latter of which there are only a few trees in one or two localities. It is distinctly a lowland community which attains its greatest development near those large rivers which overflow their banks, though small typical areas occur anywhere on low-lying swampy ground even, indeed, in dune-hollows. Although there are still wide areas of virgin forest, the great demand of late years for the timber of *P. dacrydioides* for butter-boxes has led to great destruction and in a few years, except in localities difficult of access, the association will be eradicated and the land it occupied turned into pasture.

The physiognomy of the forest is unlike that of any other. The innumerable kahikatea trees stand up side by side, the comparative slender trunks quite straight, unbranched for three-fourths their length or more, and looking like the masts of sailing-ships. The head of branches and foliage is most scanty, but in a northern or central forest bears a surprising number of huge clumps of *Astelia Solandri* (Plate XXVII, Fig. 34). Between pure kahikatea forest and the adjacent rain-forest, if such be present, are various intermediate combinations, and it is rather the tall trees of the latter which are wanting than the plants of the undergrowth, since although pools of water lie everywhere, there is always more or less moderately dry ground. Moreover fallen logs cumber the ground and these provide a station for the non-swamp tolerating species as also a place where seeds can germinate. In short, the distribution and combinations of species within the forest is regulated by the water-content of the soil. Below is given a brief account of the association at different points in proceeding from N. to S.

Near Northern Wairoa River, North Auckland district.

The kahikatea trees are more than 24 m high; their trunks are altogether hidden in many cases by *Freycinetia*. The ground is quite covered in many parts with the last-named together with much *Dryopteris pennigera* and *Carex virgata*, the whole forming a close undergrowth out of which rise vast numbers of *Rhopalostylis sapida* 9—12 m high their trunks naked and crowns sometimes touching. The general low tree and shrub vegetation is sparse and consists chiefly of *Paratrophis microphylla*, sparingly-branched *Beilschmiedia tarairi*, twiggy *Carpodetus serratus*, slender *Dysoxylum spectabile*, small *Eugenia maire*, low *Laurelia novae-zelandiae*, *Schefflera digitata* and some *Coprosma rigida*, *C. tenuicaulis* and *C. spathulata*. In places, there is a moderate amount of *Rhipogonum*. The leading ferns are: *Cyathea dealbata* and *C. medullaris* (a little), *Blechnum capense*, *B. filiforme* and *Polypodium pustulatum* (on raised tree-roots) and *Asplenium bulbiferum*. The soil is extremely wet; pools of water abound; there is much soft mud. *Podocarpus dacrydioides* is much buttressed and its roots are often raised high above the ground.

Where the forest has been destroyed, immense numbers of slender *Cordyline australis* have appeared forming a forest of tuft-trees and where the swamp is deeper a close growth of *Typha angustifolia* var. *Muelleri* [1]). Very little alteration in the depth of the permanent water would change forest into swamp or the contrary, happenings obviously correlated with a sinking or rising land-surface.

Central botanical province.

The association is the same as that described above except that the *Beilschmiedia tarairi* and other special northern plants are absent.

North-western botanical district.

The undergrowth may consist largely of *Drimys colorata*, *Carpodetus*, *Nothopanax anomalum*, juvenile *Pseudopanax crassifolium*, *Myrtus pedunculata*,

1) This applies equally to any part of the North Island, while the *Cordyline* association may in some instances be a natural one.

Coprosma tenuicaulis and *C. rotundifolia*. As ground plants, tall *Blechnum capense*, *Astelia nervosa* and *Microlaena avenacea* are everywhere and *Nertera dichondraefolia* and *N. depressa* are common. The slender trunks of the smaller trees and shrubs are thickly clad with liverworts. *Dicksonia squarrosa* is the dominant tree-fern and there is some *Hemitelia Smithii*.

Western botanical district.

Very large areas of kahikatea forest occur throughout. All the plants mentioned for the North-western forest will be present, indeed the combination is virtually the same. In some localities the *Blechnum capense* is 1.5 m in depth. *Freycinetia* is present as a liane.

Eastern botanical district.

At the time of settlement by the European there were several areas of kahikatea forest at no great distance inland, but all except a small piece near Christchurch[1]) were cut down years ago. At an earlier date, the extensive swamps, now farm-land, were occupied by forest for they contained abundant remains of trees. The above tree-association, the last of its special kind in the world, is still quite vigorous and, although it has been drained, seedling *Podocarpus dacrydioides* are produced by thousands. The species number 68 (pteridophytes 7, spermophytes 60) consisting of trees and shrubs 35, lianes 12, parasites 2, ferns 7 and herbs including grass-like plants 12. Besides the dominant *P. dacrydioides* there is abundance of *Elaeocarpus Hookerianus* and some *E. dentatus*. *P. spicatus* and *P. totara* are also present. *Paratrophis microphylla* is very plentiful. Judging from the present composition of the forest it could not have been typical kahikatea association.

The kahikatea forest of the South Otago district, now almost gone, needs no description since it was quite typical.

β. Silver-pine (Dacrydium Colensoi) association.

Further on, when treating of moor, it is shown that in the Western district that association is the forerunner of a forest-association of extremely wet ground.

The dominant tree is frequently *Leptospermum scoparium* which may be no more than a tall shrub but this serves as shelter for the silver pine which eventually may become either dominant or very plentiful. The shrub *Podocarpus nivalis* and the low tree *Phyllocladus alpinus*, both usually subalpine, are important members of the association and with them may be *P. acutifolius*, closely allied to the first-named. The substratum is wet peat and more or less *Sphagnum* is generally present.

γ. Yellow-pine (Dacrydium intermedium) association.

This association extends from the Freshwater valley in Stewart Island to the extreme S. of the island and occurs either on very wet soil or in positions

1) This was preserved by the late Mr. John Deans on whose land the forest stood and it is still religiously protected by his descendants who at the time of writing have most generously donated nearly the whole to the City of Christchurch.

exposed to furious gales. Ecologically it is closely allied to the Silver-pine association and is rather bog- than swamp-forest.

The association is clearly characterized by the abundance of the slender yellowish-green dimorphic *D. intermedium*, its shoots weeping when juvenile, the presence of great globe-like bryophyte cushions of *Dicranoloma Billardieri* and *Plagiochila gigantea* in extreme abundance measuring 60 cm × 60 cm (See Plate XXVIII, Fig. 35), the rich profusion of other mosses and liverworts and the numerous green tussocks of *Gahnia procera*. The tree-trunks are slender and close together; *Coprosma foetidissima*, so characteristic of the adjacent dryer forest, is rare; neither tree-ferns nor ordinary ground-ferns are numerous, though in gullies there is plenty of *Leptopteris superba*. The floor, where the moss-cushions do not become dominant, is quite green or yellowish-green with the thick bryophyte carpet which also clothes the tree-bases and quite encircles the slender trunks. The following are some of the specially important species: — (Hepaticae) *Aneura eriocaula*, *A. equitexta*, *Mastigobryum Mooreanum*, *Lepidozia Taylori*, *Plagiochila deltoidea*, *P. ramosissima*, *P. strombifolia*, *Schistochila ciliata*, *S. nobilis*, *S. marginata*, *Trichocolea lanata* and *T. tomentella*; (Musci) *Dicranoloma Menziesii*, *D. platycaulon*, *Hypopterygium novae-zelandiae*, *Lembophyllum cochlearifolium*, *Mniodendron comatum*, *M. comosum* and *Sciadocladus Menziesii*. The moss-cushions are filled with a network of roots from the adjacent trees, which thus procure purer water than from the peaty substratum.

The more common woody plants of the undergrowth are: — young *Dacrydium intermedium*, young *Weinmannia racemosa*, *Myrtus pedunculata*, *Nothopanax Edgerleyi*, *N. simplex*, *Griselinia littoralis*, *Styphelia acerosa*, *Suttonia divaricata* and *Coprosma Colensoi*. Small trees of *Podocarpus Hallii* and *Dacrydium biforme* are often present; *Enargea parviflora* grows in plenty on the bryophyte-cushions; the flat-leaved grass *Microlaena avenacea* is plentiful; there are extensive colonies of the plagiotropous fern *Gleichenia Cunninghamii* more than 60 cm high while the other common ferns are *Blechnum capense* and *B. discolor*.

e. Southern-beech (Nothofagus) forest.

1. General.

The lowland *Nothofagus*-forest is seldom pure, for taxads in varying abundance are present, so that there is every transition from a taxad-forest with an occasional tree of one or other of the species of *Nothofagus* to a pure formation of this latter.

The community under consideration occurs in many mountainous, or hilly districts, in the Central and Southern botanical provinces. On the Dividing Range of the North Island and on the southern slopes of Mt. Ruapehu, it forms the bulk of the montane forest which descends almost to sea-level in the S. of Wellington. In the South Island, it forms the principal forest in the Sounds portion of the Ruahine-Sounds district and in the North-western, Fiord and W. of the South-Otago districts. It is absent in the Northern botanical province, except in certain parts of the Thames sub-district, and in the North Otago and Stewart districts, while in the North-eastern and Eastern districts, it is of local distribution. All the species are present in some part or other of the range of the formation but the most common by far are *N. Solanderi*, *N. Menziesii* and *N. fusca*, the first-named being confined to the lowland-lower-mountain belt.

The species of *Nothofagus*-forest are virtually the same as those of the taxad-forest adjacent, but, in pure associations, growing, as such frequently do, under dryer edaphic conditions, more xerophytes enter in, young *Nothofagus* is an important constituent of the undergrowth, the percentage of mesophytes decreases and many of the most hygrophytic species are absent. For instance in the *N. Solanderi-N. fusca* association at Days' Bay, Wellington, the forest is open, *Styphelia acerosa*, a xerophytic ericoid-shrub, forms a considerable percentage of the undergrowth, *S. fasciculata* also is common, much of the floor is bare, the trees are but little mossed and other plants of the undergrowth are, — young *Weinmannia racemosa*, *Nothopanax arboreum*, young *Nothofagus*, *Geniostoma* and *Coprosma rhamnoides*.

2. Special details.

Ruapehu.

On the W. of Ruapehu at an altitude of about 780 m the taxad forest is succeeded by a belt of *Nothofagus Solanderi* together with abundance of *Weinmannia racemosa* as a companion tree, *Griselinia littoralis*, *Nothopanax arboreum* and *Elaeocarpus Hookerianus*. *Coprosma tenuifolia* together with young *Nothofagus* and many ordinary rain-forest shrubs &c. forms the undergrowth [1]).

On the S. of Ruapehu from some 630 m up to an altitude of about 960 m there is a magnificent piece of forest with *N. fusca* dominant, but containing also a great deal of *N. Menziesii* in many places. The trees frequently exceed 24 m in height and 1.8 m in diam. In all forests where *N. fusca* is dominant the tender green of the leaves and the somewhat open character of the foliage, as compared with that of the other southern-beeches, gives a physiognomy entirely different to that afforded by any other New Zealand tree. The undergrowth is rich and consists of nearly all the rain-forest species of the neighbourhood. *Alseuosmia quercifolia* and *Coprosma tenuifolia* [2]) are abundant. In some places there is a good deal of the handsome tuft-tree, *Cordyline indivisa* (Plate XXIX, Fig. 36). *Polypodium novae-zealandiae* is a frequent feature.

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1) The sudden change of the vegetation to this association is most striking. The adjacent belt composed of various taxads plus the conical *Libocedrus Bidwillii* offers a remarkable and striking contrast.

2) A slender-stemmed shrub 2.4 m or more high with arching habit and oblong-ovate, acuminate, thin leaves, some 9 cm long, situated on the flanks of the twigs and so turned towards the light.

East Cape district.

Both *N. fusca* and *N. Solanderi* occur but no exact details as to the associations are available.

Ruahine Mountains.

According to ASTON, there is at first a mixed Taxad-*N. fusca* association, but finally in the montane belt the latter tree is dominant. *Cordyline indivisa* is a prominent feature.

Tararua Mountains.

Both *N. fusca*, *N. Menziesii* and *N. Solanderi* are present on the eastern base of the range, the first being usually dominant and the last not greatly in evidence. *Weinmannia racemosa* is an important constituent. On the W., according to PETRIE (1908: 292), there is first a *Beilschmiedia tawa*-forest which is succeeded by a *N. fusca*-*N. Menziesii* association.

Rimutaka Mountains.

N. fusca and *N. Solanderi*, mixed or respectively dominant, form extensive associations in the lowland-belt which contain many of the ordinary rain-forest species. *Trichomanes reniforme* is frequently common as a floor-plant under unusually dry conditions and certain epiphytes become terrestial.

South Island portion of Ruahine. — Cook district.

N. Solanderi and *N. fusca* form associations almost identical with those of southern Wellington. The following northern species amongst others are present: — *Cyathea medullaris*, *Beilschmiedia tawa*, *Myrtus bullata*, *M. Ralphii*, *Coprosma grandifolia*, *Olearia Cunninghamii* and *Brachyglottis repanda*. The slender, spreading herb *Poranthera microphylla* [1]) is confined to this association. *N. apiculata* is not uncommon! *Geniostoma* is wanting.

North-western district.

N. fusca, *N. Menziesii* and *N. Solanderi* dominate throughout both lowland and montane forests, but the last-named is the least abundant. Frequently taxads, especially *Dacrydium cupressinum*, play an important part and there are all stages from more or less pure taxad-associations to pure *Nothofagus*-forest. An association of *N. fusca* and *N. Menziesii* is the most common combination. Other common trees or shrubs are: — *Drimys colorata*, *Pittosporum tenuifolium*, *Carpodetus*, *Weinmannia racemosa*, *Pseudopanax crassifolium* var. *unifoliatum*, *Nothopanax anomalum* and various species of *Coprosma* including in some places *C. grandifolia*.

North-eastern district.

Nothofagus-forest occurs on the Seaward Kaikoura Mts. but not nearly to the same extent as taxad-forest; on the continuation of the range to the S.,

1) Also found in Tasmania and Australia, but unknown elsewhere in New Zealand.

as hills merely, *Nothofagus*-associations are dominant. There were also originally considerable areas in Mason and Lottery valleys. The species are, *N. fusca* and *N. Solanderi*. There are also occasional trees of *N. Blairii* and *N. apiculata*. The undergrowth is that of eastern South Island forest in general.

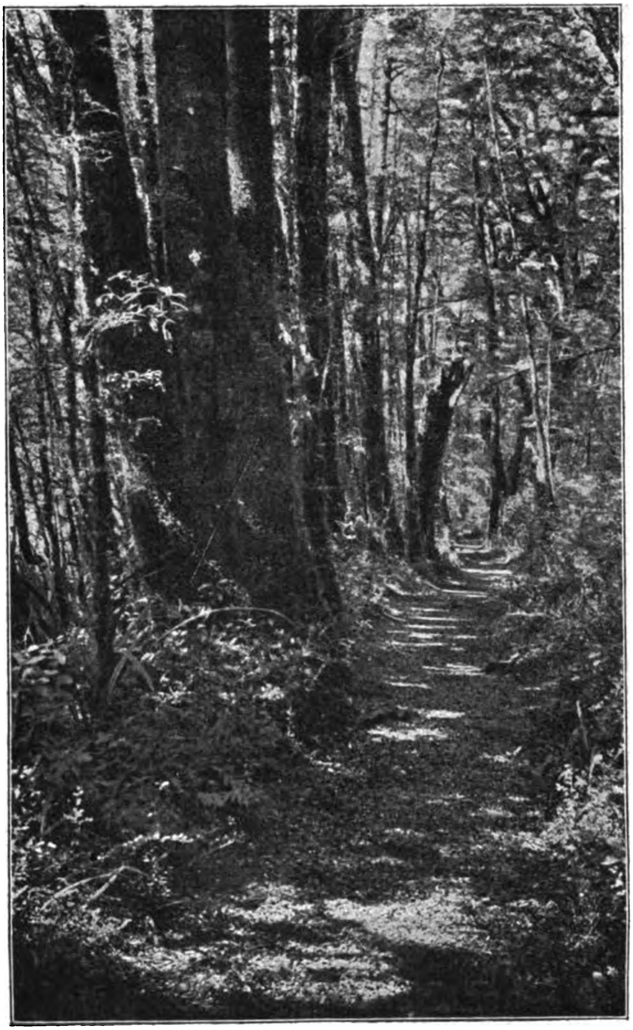

Fig. 37. Interior of *Nothofagus fusca* association, Clinton Valley, Fiord botanical district, 270 m alt. Photo E. M. Barker.

Eastern district.

There are several areas of *Nothofagus*-forest in Canterbury on the foot-hills &c. of the Southern Alps, the most extensive extending, but not continuously, from the base of Mt. Torlesse to Mt. Grey. Except in the last-named locality, where there is abundance of *N. fusca*, *N. Solanderi* is the only species.[1]) Montane *Nothofagus*-forest occurs also at Mount Somers and on the Malvern Hills.

Fiord district.

On the W. of the Divide the forest is chiefly *Nothofagus Menziesii-Dacrydium cupressinum* and is typical rain-forest with a great abundance of *Hymenophyllaceae*, bryophytes and lichens. *Nothofagus cliffortioides* descends in places to sea-level. *Phyllocladus alpinus*, *Gaya Lyallii* and *Dracophyllum longifolium* are common, also there are the usual shrubs &c. of the W. including, — *Hedycarya arborea*, *Ascarina lucida*, *Suttonia divaricata*, *Coprosma foetidissima*, *C. Banksii* and *C. Colensoi.*

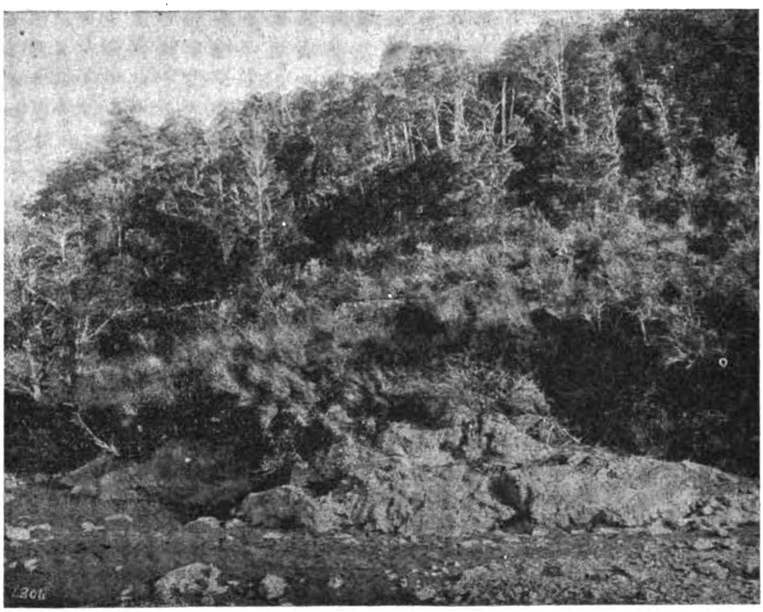

Fig. 38. *Nothofagus cliffortioides* forest giving place to tussock-steppe where exposed to excessive wind. Near source of R. Poulter, Canterbury, at junction of Eastern and Western districts. Photo L. Cockayne.

To the E. of the Divide, there are far fewer taxads, nor do these ever dominate. *N. Menziesii* is the leading tree. *N. Solanderi* is common in some localities. *N. fusca* forms pure associations (Fig. 37).

South-Otago district.

Nothofagus-forest occurs abundantly in gullies throughout the montane belt. *N. Menziesii* is the commonest association. The undergrowth &c. is similar in species to that of lowland taxad-forest of the district. In the S. of the

1) *N. fusca* may occur in some of the pieces of forest between that at Glentui and Mt. Grey, but all information is lacking.

district the association is much more local and absent over wide areas. It is well developed on the E. of the Longwood Range where however it is frequently mixed with abundance of *Dacrydium cupressinum*, *Podocarpus ferrugineus* and *Weinmannia racemosa*. On the southern-beech here there are immense parasitic shrubs of *Elytranthe Colensoi* 6 m high and nearly as much through. *Dicksonia fibrosa* is a common tree-fern.

2. Heath.

a. General.

Heath falls into two classes according as shrubs or fern (*Pteridium*) dominate; between the two are intermediates. How far the formation, as at present constituted, existed in primitive New Zealand is hard to say. Assuredly, it was much less extensive, and possibly there are but few places where it is virgin at the present time, though usually no community carries on the face of it a more primitive stamp. Heath is related to forest; also shrub-heath, at times has so great an affinity with moor that it is hard to draw a line of distinction.

Heath, though generally lowland or montane, ascends to 900 m on the Volcanic Plateau. It is specially abundant in the Northern botanical province, where it occupies what are termed locally the "gum-lands". In the Central and Southern provinces, fern-heath is the more common of the two classes.

Shrub-heath is frequently closely related to moor but the generally smaller amount of peat in the substratum and its greater dryness are important edaphic differences. Many of the species are the same, but there is a larger forest-element in heath. The soil may be clay, loess, pumice, gravel or sand. It may vary much in its water-content, and this fluctuates considerably according to the season of the year, whereas bog-soil is permanently wet.

There are about 114 species throughout the area of which 38 are low trees and shrubs, 8 lianes, 2 parasites, 41 herbs, 10 grass-like plants, 4 rush-like plants, 7 ferns (excluding climbers) and 4 lycopods (excluding climbers). Many species are confined to the Northern botanical province and the number decreases considerably from N. to S.

b. Shrub-heath.

1. General.

Leptospermum scoparium is nearly always the dominant shrub; at times it is almost pure. Probably, in primeval New Zealand the present association was represented by low *Leptospermum*-forest, such as yet remains in parts of the N. and which merges into forest proper. In other parts, where the soil was wet and sour or gravelly, sandy and dry, there would doubtless be low *Leptospermum*-heath much as it is yet. Forest, in many parts, when burnt, is succeeded by shrub-heath, but one must not conclude that such is a reversion to primitive conditions. As for the formation itself, burning again and again has altered the original arrangement altogether and the relative abundance of the species must have been markedly altered, while each burning would cause a rearrangement. Especially is this the case in the N., where, as may readily be seen, a series of fires transforms shrub-heath into fern-heath, for a time, at any rate. Bearing the above in mind, who can say that even so common a plant as *Pomaderris phylicaefolia* was not comparatively rare in primitive New Zealand?

Shrub-heath is of varied origin. It may be a natural replacer of rain-forest, a succession-stage after moor or after river-bed, or a new-comer after the forest is destroyed by man. Between the natural and the artificial it is now, in most cases, impossible to discriminate.

The dominant ecological character of the association is the prevalence of the ericoid-form amongst its members, 17 species of woody plants possessing it to a marked degree. The number of tuberous-rooted orchids is a rather striking feature, but they give no distinctive mark to the vegetation.

2. Gumlands' Heath.

Modified though this is by man, it contains as a rule[1]) few introduced plants and is a clearly-defined and striking association. It covers much of those deep, clay soils that form so large a part of the surface of the Northern province. At one time kauri forest occupied this ground as evidenced by the abundance of fossil resin and even undecayed logs beneath the surface. The clay varies in colour from brick-red, by way of orange and yellow, to almost white, this latter being especially barren. In winter it becomes saturated with water, but, in summer, baked by the sun, it is extremely dry and opens out into many cracks. Hollows and low-lying ground are always filled with peaty water or at least remain permanently wet providing where wettest bog-conditions; here their vegetation is treated as moor.

The species number about 81, the following of which, absent in southern heaths, are more or less common in this association: — *Lycopodium densum*, *L. cernuum*, *Phylloglossum Drummondii*, *Paspalum scrobiculatum*, *Schoenus tendo*, *Lepidosperma laterale*, *Cordyline pumilio*, *Thelymitra pulchella*, *Persoonia toru*, *Cassytha paniculata*, *Weinmannia sylvicola*, *Carmichaelia australis*, *Pomaderris elliptica*, *P. Edgerleyi*, *Leptospermum lineatum*, *Halorrhagis incana*, *Veronica diosmaefolia*, *Lagenophora lanata*, and *Olearia furfuracea*.

A typical area of gumlands' heath shows many level breadths of *Leptospermum scoparium*, in one or other of its varieties, varying from perhaps 3 m to a few centimetres in height. Where tall, the plants are crowded with long, straight, bare, blackish stems and small heads of short leaf-bearing branches. Frequently there is a more or less dense undergrowth of the green rush-like stems of *Schoenus tendo* mixed with and overtopped by the yellowish-green pine-like *Lycopodium densum*, or they may grow separately. Probably there will also be some *Pteridium*, *Pomaderris phylicaefolia* and *Styphelia fasciculata*.

1) Further on it is shown how certain Australian species have gained a footing.

The vast number of seeds, and their ready germination, bring seedlings of *Leptospermum* in their thousands after fire, while contemporaneously other denizens of the heath reproduce themselves, though in smaller numbers. Where, for example, the *Leptospermum* is 1. m high, *Dracophyllum Urvilleanum* raises its slender, branched stem 50—90 cm above the dull mass of foliage. So too, *Epacris pauciflora*, but it is not quite so tall. Also the rush-like stems of the *Schoenus* pierce through the close growth, but these not as seedlings but as new shoots from the undamaged rhizome. Sometimes the fire encourages the growth of pure *Pteridium*, for its rhizome being unhurt by fire, new leaves are rapidly put forth which check the establishment of seedlings. Wetter ground is marked by an abundance of *Cladium teretifolium*, or green masses of *Gleichenia dicarpa* but these belong more properly to moor.

Where the ground is dry and the plants of *Leptospermum* further apart, *Pomaderris phylicaefolia* is abundant, green flat-stemmed tussocks of *Lepidosperma laterale* stand here and there and in some localities *Pomaderris elliptica* and *P. Edgerleyi* (Plate XXX, Fig. 39) are characteristic as also *Lycopodium densum* and *L. cernuum*, especially the former. *G. circinata* often climbs over the bushes of *Leptospermum*[1]). When the varied forms and colouring of these plants are considered, it can be understood that gumlands' heath is far from being a monotonous spectacle.

When the heath is near a forest there are, to the N. of the Northern Wairoa River, many young non-flowering trees of *Weinmannia sylvicola* with yellowish-green, long pinnate leaves and frequently young trees of *Knightia*; occasionally a stunted kauri may be encountered. Near the coast more especially *Olearia furfuracea*, most showy with its masses of white flower-heads, gives a special character to be heath, and it is often accompanied by the small tree *Persoonia toru*[2]).

3. Pumice-heath.

This belongs to the Central province and is confined to the Volcanic Plateau. The substratum consists of unchanged pumice with a variable amount of surface-humus. Even where the rainfall is heavy the station is xerophytic. The special species are *Dracophyllum subulatum*, an erect dull-coloured shrub some 60 cm high with slender, twiggy fastigiate branches, small, erect, stiff

1) The following are also common members of the association: — *Lindsaya linearis, Danthonia pilosa, D. semi-annularis, Gahnia gahniaeformis, Cordyline pumilio, Dianella intermedia, Drosera auriculata, Leptospermum lineatum, L. ericoides, Pimelea prostrata* var., *Styphelia Fraseri, S. acerosa* and *Lagenophora lanata.*

2) The following interesting plants are of restricted distribution: — *Gleichenia flabellata* with its semi-horizontal, glossy green pinnae may occupy several sq. metres at a time; *Todaea barbara*, its short, massive trunk hidden by the close semi-globular mass of Osmunda-like leaves grows in open places amongst *Leptospermum*, it is confined to the far *N.*; *Cassinia amoena* is restricted to the North Cape Hill; *Veronica diosmaefolia* makes pure stands in some localities; *Loxsoma Cunninghamii* grows in shade of *Leptospermum* near margins of forests; *Cassytha paniculata* binds shrub to shrub with its slender, twine-like stems; it is confined to the far N.

coriaceous, pungent, very narrow leaves about 2.4 cm long and deeply-descending roots and *Gaultheria oppositifolia*, a much-branched, spreading low shrub with thick, opposite coriaceous leaves 4—6 cm long. The *Dracophyllum* frequently forms almost pure colonies and marks the most xerophytic station and poorest soil. In many parts *Leptospermum scoparium* is dominant associated with *Danthonia semi-annularis*, *Gahnia gahniaeformis*, *Dianella intermedia*, *Persoonia toru*, *Coriaria ruscifolia*, *Leptospermum ericoides*, *Ganltheria oppositifolia*, *Styphelia acerosa*, *S. fasciculata*, *S. Fraseri* and *Dracophyllum subulatum*. At the highest altitudes e. g. near Rangitaiki, *Phormium Cookianum* is abundant and there is *Raoulia australis* and *Cassinia Vauvilliersii*[1]).

4. Heath in south of the North Island.

In the Ruahine-Cook district, heath occurs on dry slopes and ridges on the outskirts of lowland *Nothofagus* forest, and may, in many cases occupy a burnt forest-area.

Besides the dominant *Leptospermum* the following shrubs and young trees are common: — *Nothofagus Solanderi* (if close to forest), *Weinmannia racemosa* juvenile, flowering), *Nothopanax arboreum* (if near forest), *Gaultheria antipoda*, *Styphelia fasciculata*, *S. acerosa*, *Coprosma lucida* and *C. rhamnoides*. In the undergrowth there may be *Gahnia setifolia*, *G. pauciflora*, *G. gahniaeformis* and *Cladium Vauthiera*.

Near the sea, the scrub will consist chiefly of *Cassinia leptophylla*. In rather exposed places, *Clematis Colensoi* var. *rutaefolia* may be a common liane. River-bed may have a heath chiefly of *C. leptophylla*. This species is much more abundant than in primitive New Zealand.

5. South Island heaths.

Cassinia leptophylla-heath occurs in the northern part of the North-east district. Besides *Leptospermum scoparium*, there is frequently little else in most heaths of the South Island though *Styphelia acerosa* is generally present as undergrowth. The *Leptospermum* association of the North-western district is dealt with as moor.

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1) The eruption of Tarawera, 26 years ago, covered a vast area of pumice-heath with a more or less thick covering of volcanic ash. Near the centre of eruption the vegetation was buried to a depth of many metres so that quite new ground was available for colonization. Nineteen years after the eruption I paid a special visit to the new ground. Rain, early on, had carved the loose slopes into gully-like channels 9 m or more deep and these were filled with a close growth of *Arundo conspicua* mixed in places with *Coriaria ruscifolia* this latter forming green patches. The flatter ground contained only plants here and there of which *Danthonia semi-annularis* and *Calamagrostis avenoides* var. *brachyantha* were dominant. A species of *Cladonia*, another lichen, a moss or two, *Pteridium*, *Weinmannia racemosa*, *Gaultheria antipoda*, *G. oppositifolia*, and *Raoulia tenuicaulis* were also present. There was a good deal of the introduced *Trifolium repens*, *T. minus*, *Holcus lanatus* and *Hypochaeris radicata*, but they had probably been sown by man.

Gravel-plains' heath (North-eastern and Eastern districts).

A low rainfall, combined with a substratum consisting chiefly of rounded stones, favours *Leptospermum*-heath. There is a variable amount of surface-soil consisting of a loamy sandy clay mixed with 20 to 50 p. c. of stones. Although apparently flat, the surface will consist of hollows and ridges. Both *L. scoparium* and *L. ericoides* will be present. Where the shrubs are close, there will be a good deal of a species of *Hypnum* on the ground, and to this in part the humus-content of the soil is due. The spinous *Discaria toumatou* and the yellow-leaved *Cassinia fulvida* may be common. In open spaces, in the most stony areas, there will be abundant silvery mats of *Raoulia lutescens* and probably some *R. tenuicaulis*, while cushions of *Scleranthus biflorus* will be also present. *Carmichaelia subulata* may be common.

Stewart Island heath.

Much of the *Leptospermum*-association is situated on ancient dunes and has already been dealt with in the coastal section. Near Port Pegasus there is a good deal of close-growing *Leptospermum*, but it is treated along with the allied association of the mountains.

c. *Fern-heath.*

Fern-heath is a most common formation. The dominant species is *Pteridium esculentum*. How far any fern-heath, at the present time, is a natural formation I do not know. Repeated burning of shrub-heath, of forest and even of steppe, in some cases, will establish fern-heath. Even in the wet climate of the North-western district *Pteridium* may be seen making its appearance as soon as the forest is burnt.

In New Zealand, except in specially exposed localities, the fern is evergreen, consequently there is no spring ground-vegetation, as in Europe. Indeed, the close growth of the leaves inhibits all undergrowth except in open places. Luxuriant fern-heath is frequently more than 1.5 m high. Such will be quite pure, the floor will be bare, but there will be an abundance of dead fronds.

In the Northern botanical province, since shrub- and fern-heath intergrade, the latter may in places contain a good many of the northern shrubs. The commonest constituent throughout the formation in both islands is *Coriaria ruscifolia*, which after repeated burnings of the fern may become the sole plant, owing to its powerful and far-spreading underground stem and its aerial organs being annual merely.

3. Water-Associations.

Under the above head are included associations of plants specially adapted to the aquatic-life and occupying permanent still or flowing fresh-water. Here, only the vascular-plants are dealt with[1]). The total number of species con-

1) This is not because there is any lack of fresh-water *Algae* or bryophytes, but the species of the former have been little studied as yet while nothing is known as to their combinations into associations.

cerned is but 26, which belong to 12 families and 15 genera and comprise 5 free-swimming plants, 8 soil-rooted and leaf-floating, 10 submerged and 3 amphibious.

On still waters throughout New Zealand proper, Stewart Island excepted, the floating water-fern, *Azolla rubra*, the individual plants only 1.2—2.5 cm long, forms close, red sheets several centimetres thick quite hiding the water-surface, which, by the inexperienced, might be mistaken for dry ground. Such an *Azolla*-association is generally quite pure, though it may occupy the water-surface of open swamp. The two floating species of *Utricularia* (*U. protrusa*, *U. Mairii*) are extremely rare, the former having been observed only on Lake Tongonge in the far N. and Lake Waihi (Waikato) and the latter may be extinct as it was noted only in the Lake Rotomahana which was destroyed by the eruption of Tarawera. *U. protrusa* forms floating colonies 60 cm or more across.

Where the water is comparatively still and shallow, as near the margins of lakes and slow-flowing rivers, or on the surfaces of ponds and shallow streams, there are frequently wide breadths of the brownish, long-petioled leaves of *Potamogeton Cheesemanii* [1]), their coriaceous, oblong blades some 2.5 cm long, while, beneath the surface, there are, in abundance, the short-petioled, translucent, ribbon-like leaves generally slowly moving with the current. In similar stations are the amphibious *Myriophyllum elatinoides* and *M. propinquum* forming masses of floating stems with submerged finely-cut leaves, but having also aerial stems with entire leaves [2]). *Callitriche verna* is another species of still water.

The submerged water-plants, some of which have been dealt with as coastal, are as follows: — *Pilularia Novae-Zealandiae*, *Potamogeton ochreatus*, *P. pectinatus*, *Zannichellia palustris*, *Althenia Preissei*, *Ruppia maritima* and with these may perhaps be included *Ranunculus Limosella* and *Glossostigma elatinoides*.

4. Swamp.

a. General.

By swamp is here meant those plant-associations which occupy loose, frequently peaty soil, which is always more or less covered by a shallow layer of water. It is the representative, in New Zealand, of the "Niedermoor" of German and the "Fen" and "Carr" of English writers. Except forest, no formation has been so changed or eradicated by man, but, except in certain localities, areas, more or less unaltered, still persist, so that a general idea of New Zealand swamp may be gained, even if a detailed study is no longer possible.

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1) Or of *P. natans* or *P. polygonifolius* as the case may be.

2) The handsome *M. robustum* is included above in my estimate of aquatic plants since it shows, at times, a certain amount of heterophylly, but it is dealt with under the heading "swamp".

Swamp originates in various ways, the most common being from the gradual occupation of lake by aquatic plants in the first case and swamp-species in the second, or from rivers frequently and regularly overflowing their banks. In any case, through the decay of the dead plants, in course of time, considerable accumulation of peat takes place, a sour soil is produced and bog-conditions may follow; but, on the other hand, swamp-tolerating shrubs, and then trees may enter the association, and, as already described, first swamp-forest and then ordinary forest form a climax. Also, of course, there may be the reverse.

The number of swamp-species excluding aquatics is about 65, which belong to 16 families and 32 genera; their growth-forms and the number of species in each are: — trees 1, shrubs 8, herbs 13, lianes 1, grass-like plants 16, rush-like 24 and ferns 2. Besides many typical helophytes, e. g., the majority of the grass- and rush-like plants, there are xerophytic shrubs (*Carmichaelia paludosa*, *Dracophyllum virgatum*, *Coprosma propinqua*, *Olearia virgata*) and mesophytic shrubs (*Veronica salicifolia* and its var. *paludosa*, *Coprosma Cunninghamii*). About 36 species are virtually confined to swamp, many of the remainder occur principally in wet ground, but 8 species, at any rate, occupy ordinary mesophytic or even strongly xerophytic stations. The leading physiognomic plants are: — *Typha angustifolia* vars. *Muelleri* and *Brownii*, *Carex secta*, *Phormium tenax* and *Leptospermum scoparium*.

b. Reed-Swamp and its allies.

1. Raupo (Typha)-association.

This association occurs in abundance from sea-level to an altitude of 750 m on all kinds of soil, including sand, so long as covered with water all the year round; it is absent in Stewart Island. The *Typha* may dominate, or *Phormium tenax* be present in equal quantity; in any case, the former is the first-comer and can occupy water too deep for the well-being of *Phormium*. On the other hand, natural or artificial draining leads to the dominance of *Phormium* which thrives far better on a rich, well-drained soil than in swamp.

The following species, abundant in the Northern botanical province, occur also, to some extent, in the North Island portion of the Central Province, but are rare or absent in the South Island: — *Sparganium antipodum* (rare in North-western district), *Isachne australis* (to Volcanic Plateau and N. of Egmont-Wanganui districts), *Elaeocharis sphacelata* (occasionally on W. of South Island to Stewart Island), *Cladium articulatum* (E. Cape district).

A well-developed Raupo-swamp, in the N., consists of close-growing *Typha*, 1.8 m or more high, their leaves pale-green, stout and erect. There will be a dense undergrowth of *Isachne australis*[1]), its long shoots intermingled, and

1) A perennial grass with long, slender, green, more or less prostrate stems and short, thin flat, bright-green leaves about 10 cm long frequently held horizontally.

Polygonum serrulatum[1]), Raised above this stratum, and growing through it, may be an abundance of *Epilobium pallidiflorum*, perhaps 90 cm high and bearing in summer numerous handsome white or pale rose-coloured flowers 1.2 cm in diam. The floor of the association will be excessively wet, and but for the close undergrowth and decaying vegetable matter, one could hardly penetrate such a swamp. Here and there will be occasional plants of *Elaeocharis sphacelata*[2]), the rush-like *Cladium teretifolium*, *Sparganium antipodum*[3]) and perhaps an occasional example of *Carex secta* and *Phormium tenax*. Where the swamp is a trifle dryer great colonies of pure *Cladium articulatum* may appear, perhaps 1.5 m high, its stems erect, terete, close together with pungent leaves of nearly equal length. Pure masses of *Carex pseudocyperus* var. *fascicularis* 1.2 m high too, may be extremely abundant. Other plants of this association are: — *Blechnum capense*, *Scirpus inundatus*, *Schoenus Carsei*, *Cladium Huttoni*, *C. glomeratum*, *Carex virgata*, *Epilobium chionanthum*, *E. erectum*, *E. insulare*, *Hydrocotyle pterocarpa*, and, in open water, some of the aquatic plants.

In the South Island, Raupo-swamp contains far fewer species, otherwise its physiognomy and ecology are the same. At an altitude of from 550—750 m, in the South Island, where there is a steppe-climate, it may contain in addition to *Typha* a girdle of *Carex secta* in the shallower water and also *C. subdola* and *C. ternaria*. Change to dryer conditions in such swamp, if there is sufficient rain-fall, will bring *Sphagnum*-moor.

2. Phormium-swamp.

At the present time quite a wrong estimate might be gained as to the relative importance of this association as compared with that of *Typha* in primeval New Zealand, since many of the extensive areas of *Phormium*-swamp that now exist have arisen through the draining of Raupo-*Phormium*-swamp where *Typha* was easily dominant. But areas large and small persist in many places where the natural transition from dominant *Typha* to dominant *Phormium* can be seen.

Where the *Phormium* is dense, its masses of rhizomes monopolize the surface and its frequently more or less drooping leaves cut off the light. But where there are open spaces, the usual swamp-plants of the particular locality are present. *Carex secta* may play a conspicuous part. On the dryer ground there may be tussocks of *Arundo conspicua*. *Blechnum capense* may be an

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1) A perennial herb 30—60 cm high with a creeping, rooting, flexible, hollow stem which finally ascends, and branching but little, bears thin, yellowish-green blotched lanceolate leaves, 8 cm long by 1.5 cm broad.

2) A perennial rush-like herb with stout, creeping, stoloniferous rhizome and stout, cylindrical, hollow, erect, septate stems 60—90 cm high.

3) A perennial herb 30—60 cm high with rather slender, creeping rhizome, cord-like roots with short lateral rootlets and long, bright-green, almost triquetrous leaves 2—3 mm broad, their bases sheathing.

important constituent of the undergrowth. Shrubs are generally present more or less, especially, — *Leptospermum scoparium*, *Veronica salicifolia*, *Coprosma propinqua* and *C. Cunninghamii*, these the forerunners of shrub-swamp. Where there is open water, there may be colonies of *Azolla* or *Lemna minor*, or floating *Potamogeton*, *Ranunculus macropus*, *R. rivularis* or *Cotula coronopifolia*.

Phormium tenax and *Arundo conspicua* frequently form lines on the margins of rivers. Here too, or elsewhere, where there is muddy ground subject to frequent wetting, may grow: — *Crassula Sinclairii*, *Myriophyllum propinquum* (as land-plant), *Elatine americana* var. *australiensis* and *Limosella aquatica*.

3. Niggerhead (Carex secta)-association.

Here shock-headed masses of *C. secta* are dominant raised above the water on their massive "trunks" 60 cm — 1.4 m high. These trunks not only remove the actual living portion of the *Carex* from swamp-conditions but their sides afford a station for *Blechnum capense*, *Hydrocotyle pterocarpa*, *Hierochloe redolens* and seedling shrubs. Niggerhead-swamp contains many of the ordinary swamp-plants and many transitions occur between it and *Phormium*- or Raupo-swamp.

4. Stewart Island swamps.

As far as the swamps of Stewart Island have been investigated, they are closely related to moor. The main point of importance is that the coastal *Leptocarpus simplex*[1]) is often dominant making pure colonies. In other places *Cladium glomeratum* and *Carex ternaria* respectively form close masses. Other species of importance are: *Blechnum capense* (stunted), *Carex stellulata*, several common species of *Hydrocotyle*, and where wettest, *Carex secta*.

c. Associations of warm-water, or of hot ground exposed to steam.

According to SETCHELL, various Schizomycetes flourish in the numerous hot-water pools of the Volcanic Plateau, but none can endure a higher temperature than 75° C. Where the heat is moderate, then *Cyanophyceae* occur. On shrubs, constantly exposed to steam, the twigs become deeply coated with the orange-red alga *Chroolepus aureus*.

The following ferns and lycopods grow luxuriantly near hot-water streams, their roots in strongly heated soil and their aerial parts exposed to steam: — *Histiopteris incisa*, *Dryopteris gongylodes*, *D. parasitica*, *Nephrolepis cordifolia*, *Gleichenia linearis*, *G. dicarpa*, *Schizaea dichotoma*, *Lycopodium cernuum* and *Psilotum triquetrum*. *Histiopteris incisa* and *Lycopodium cernuum* are of common occurrence, the latter constantly hugging the warm ground round steam vents, but the other species are of local distribution.

On the sides of the boiling wells which supply the Boiling River (Otumakokori Stream) *Dryopteris parasitica*, *Nephrolepis cordifolia* and *Gleichenia*

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1) The extensive swamp near L. Brunner, North-western district, contains abundance of this plant.

linearis grow in great abundance in a hot atmosphere always saturated with moisture[1]).

Hot water swamps contain many ordinary swamps-plants, e. g.: *Typha*, *Scirpus lacustris*, *Elaeocharis sphacelata*, *Cladium articulatum*, *Carex ternaria*, together with *Dryopteris parasitica*. The latter, according to KIRK, formerly covered acres of the swamp on either side of the warm river connecting lakes Rotomahana and Tarawera, "its dull green fronds sometimes five feet high and seven inches across but in this state it is usually barren". The same fern grew in abundance also on the "White Terrace", covering "the thin crust overlying the scalding mud and from its erect, rigid habit and the strict sori-laden pinnules presenting a forcible contrast to the luxuriant swamp form".

On the shore of Lake Rotorua at Ohinemutu, growing on heated ground or where there is an excess of certain salts &c. in the soil, is *Fimbristylis dichotoma* and the presence of the following coastal plants may perhaps be correlated with the edaphic conditions: *Bromus arenarius*, *Scirpus maritimus*, *Carex pumila*, *Leptocarpus simplex*, *Juncus maritimus* var. *australiensis* and *Ranunculus acaulis*.

Where the heath-association[2]) comes into close proximity with steam of a certain character or on to soil containing salts &c., as mentioned above, the formation becomes open and by degrees the species give out excepting *Leptospermum ericoides* and *Styphelia fasciculata*, but the former becomes an altogether prostrate, rooting plant, whereas the latter remains erect. Where steam charged with sulphur-fumes strikes, vegetation is absent. Round boiling-mud holes the shrubs are erect and luxuriant. *Lycopodium cernuum* can tolerate far more hot steam, heated soil and fumes than any other heath-plant.

d. Shrub-swamp.

Either through the presence of *Carex secta* "trunks", the raising of the surface in places by gradual deposition of peat, or the occurrence of areas dry occasionally, affording positions where the seeds of shrubs can germinate, shrubs may gradually invade a swamp, and, in course of time, become the dominant species.

The dominant plant is nearly always *Leptospermum scoparium*, which may form a most close growth of straight, slender stems. *Cordyline australis* is very frequently an accompanying plant, and as already seen, when dealing with forest, it may make a pure, low-tree association. Other shrubs of the formation are: — *Carmichaelia angustata* (North-western district), *C. gracilis* (Eastern and North-Otago districts, but rare), *C. paludosa* (Western district), *Coriaria ruscifolia*, *Eugenia maire* (North Island), *Pseudopanax crassifolium*, *Griselinia littoralis*

1) For further particulars see HOCHSTETTER (1867: 402) and KIRK (1873 b: 336), but the statements as to all these "hot-water" ferns being confined to such a station is now known to be incorrect, only *Nephrolepis* and *Gleichenia linearis* being so restricted.

2) This really belongs to the part dealing with heath, but its description appropriately follows that of the effects of hot-water &c.

(W. of South Island), *Veronica salicifolia* and its var. *paludosa* (W. of South Island), the species of *Coprosma* already cited, *Olearia laxiflora* (Western district).

Shrub-swamp may also be a stage in the retrogressive evolution of swamp from swamp-forest, in which case, at first, many forest-plants persist for a time. *Leptospermum*-swamp strongly favours the presence of *Sphagnum* and thus is readily transformed into the different ecological category of moor.

5. Moor.

a. General.

Wherever there is a soil which remains saturated with water at all seasons, a moor-association of some kind will be present. But, although there may be shallow pools here and there, the entire surface must not be permanently covered. According to the average degree of wetness, so will the plant-covering vary, *Sphagnum*-moor (-bog), occupying the wettest and shrub-moor the dryest ground.

The amount of peat present regulates the species to some degree, but to a lesser extent than would be imagined. Where the peat-content is scanty, "Pakihi-moor" occurs and forms a connecting link with *Leptospermum*-heath.

Well-developed moor shows a distinct succession of vegetation. First, comes *Sphagnum*-bog; it is succeeded by various related combinations of species in which rush-like *Cyperaceae* and the xerophytic *Gleichenia dicarpa* with its plagiotropic pinnae and their pouch-like segments, is dominant. Finally, this is followed by heath or low forest, which latter may be replaced by rain-forest.

Moor appears to originate in various ways, e. g.: from lake by way of reed-swamp; from frequent floods causing swamp in the first place; from water lying in wet hollows; from an excessive rainfall on flat badly-drained ground and from *Sphagnum* settling on the forest-floor in a wet climate.

Obviously an abundant rain-fall, a comparatively low summer temperature and frequent cloudy skies favour moor, which is thus a common feature of the W. and S. of the South Island and Stewart Island. In the North Island, extensive *Sphagnum*-bogs were present on the Waikato Plain, but these were edaphic rather than climatic and arose in swamps caused by overflow of the river and defective drainage. So, too with certain bogs, now reclaimed, on the Canterbury Plain, where the climate is hostile to moor. Hollows in the Auckland gumlands are occupied by moor, and it is a matter of choice whether to call a good deal of the vegetation heath or moor.

Many moorland species, especially in the Southern botanical province, are also subalpine or alpine, while the moorland of Port Pegasus, Stewart Island is virtually identical with that at 600 m altitude, and upwards.

The growth forms[1]) are varied and include the following: — ericoid-shrub, creeping-shrub with underground stem, rush-form, grass-form, tussock-form,

1) The far-creeping subterranean stems of certain species is probably the most important adaptation leading, as it does, to enormous vegetative increase and consequent dominance of a species over a wide area.

cushion-form, prostrate creeping-herb, *Gleichenia*-form, rosette-herb, summer-green tuberous-form. Generally speaking, xerophytic structure is present to a considerable degree.

The total number of species is about 106, which may be classified as: shrubs, 8; herbs and subshrubs, 59; grass-like plants, 15; rush-like plants, 11; ferns, 9; lycopods, 4. The following are especially important species: *Gleichenia dicarpa*, *Lycopodium ramulosum*, *L. laterale*, *Hypolaena lateriflora*, *Cladium teretifolium*, *C. glomeratum*, *C. Vauthiera*, species of *Drosera*, *Leptospermum scoparium*, species of *Utricularia*, *Halorrhagis micrantha* and species of *Sphagnum*.

b. The moor associations.

1. Sphagnum-Gleichenia-moor.

This association occurs on wet areas amongst manuka-heath; in open spaces in forest, and as a stage in the succession from lake and following swamp. On the Waikato Plain a combination of swamp and moor was common in primitive New Zealand.

The amount of *Sphagnum* varies much in different places. Frequently, there are pale straw- or cream-colored cushions separated from one another by dark, soft peaty ground where coffee-coloured water lies. Or, development has advanced, the cushions grow into one another forming a continuous covering of soft moss saturated with water, except after a period of drought when the surface may be dry. Almost always there are a number of species growing on the moss, some of which will be absent elsewhere on the moor, for the upper surface of the cushion contains a purer water than moor-soil in general. Between the *Sphagnum* and its occupants there is a "struggle" for the mastery, for the moss by its upward growth tends to bury any plant whose upward growth is too slow.

The following are common on *Sphagnum*-cushions throughout: — *Blechnum capense*, *Gleichenia dicarpa*, *Cladium teretifolium*, *C. Vauthiera*, *Hypolaena lateriflora*, *Drosera binata*, *D. spathulata*, *Leptospermum scoparium*, *Halorrhagis micrantha*, *Hydrocotyle asiatica*[1]).

Where *Sphagnum* is either absent, or merely in scattered patches, and the soil consists of soft, wet peat, a low green carpet of *Gleichenia dicarpa* frequently covers many square metres of ground, and, as it can be recognized from a considerable distance, it is the physiognomic indication, par excellence, of the association. In other places, the rush-form is physiognomic, the species being *Cladium teretifolium*, a plant of wetter ground than the *Gleichenia* from which it is distinguished by its darker green. In other places again, wide areas are occupied by *Hypolaena lateriflora*, a restiaceous plant with slender, wiry, flexuose, leafless, semi-prostrate stems which frequently form thick brownish masses 60 cm—1 m in depth mixed or unmixed with *C. teretifolium*.

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1) In the South Otago district and Stewart Island *Carpha alpina* (generally subalpine), *Gunnera prorepens*, *Gaultheria perplexa* and *Celmisia longifolia* var. are common.

The moor-vegetation is generally stratified, the fern and sedges, already mentioned, forming the upper layers, or where both occur, the sedges overtop the fern. The ground-layer may consist of low-growing creeping species of *Lycopodium*. This is the case in the Western district where *L. ramulosum*, flattened close to the soil, covers extensive areas. Further N. *L. laterale* of similar growth-form, but with more erect stems, is the common moor-species.

On bare places as well as on *Sphagnum* are the tiny red rosettes of *Drosera spathulata* pressed closely to the substratum. Several species of *Utricularia* are common, e. g. *U. delicatula* in the far N. of Auckland, the flowers white with a yellow eye, and *U. novae-zelandiae*, its flowers pale purple while in the South Island it is the beautiful *U. monanthos* with bright purple flowers and yellow eye. Mention must be made of the bamboo-like *Lepyrodia Traversii* whose stout flexible stems, erect and crowded, are at times 3 m high[1]).

The moor of the South Otago district, but especially that of the S. of Stewart Island, is remarkable for the mountain-plants it contains. For instance, in the latter are cushions of *Oreobolus pectinatus*, *Donatia novae-zelandiae* and *Celmisia linearis*, in fact its composition is almost identical with that of the subalpine bog of the district. The heath-like *Styphelia empetrifolia*, the beautiful blue *Thelymitra uniflora*, *Viola Cunninghamii*, the small rosettes of *Oreostylidium subulatum* and the grass-like *Herpolirion novae-zelandiae* are all interesting semi-mountain members of South-Otago and Stewart moors.

In both the above districts, too, the tall tussocks of *Danthonia Raoulii* become established on *Sphagnum-Gleichenia* moor and tussock-moor results, which as the ground becomes dryer changes to tussock-steppe. Somewhat similar is the occupation of Western district moor by the great tussocks of *Gahnia rigida* which may take complete possession, but here the relationship is with forest not steppe.

2. Heath-moor.

Even on moor, such as described above, there is usually more or less *Leptospermum scoparium*, and then it is only a question of time for this to become dominant and heath-moor established. Beneath the *Leptospermum* a good many of the moor-species continue to thrive, thanks it may be to some epharmonic change. Thus *Hypolaena* and *Gleichenia* become semi-lianes and *Lycopodium ramulosum* grows erect, increases its stature and almost ceases to develop sporophylls. Or the heath-moor may be distinguished, as in some parts of Stewart Island, by the presence of certain shrubs either in clumps or dotted about, rather than by the dominance of *Leptospermum*[2]).

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1) This remarkable plant, though very common in the Chatham Islands, has only been recorded from one bog-area in the Waikato and from the neighbourhood of Kaitaia (N. of North Auckland district).

2) The following shrubs occur in shrub-heath in the South Otago district or Stewart Island: — *Dracophyllum longifolium* (often common on *Sphagnum* cushions in forest openings), *Coprosma parviflora*, *C. rhamnoides*, *Veronica buxifolia*, *Cassinia Vauvilliersii*, *Olearia virgata*.

Near Lake Manapouri to the E. there is an extensive shrub-moor. There is a great depth of peat. *Dracophyllum Urvilleanum* (one of its varieties) forms so close a mass that nothing else can be seen at even a short distance away. Within the scrub there is *Sphagnum*, *Hypolaena*, *Cladium teretifolium*, *Oreobolus strictus* and other bog species.

A rather remarkable association occurs on those flat, badly drained areas of the North-western and Western districts known by the Maori name of "Pakihi". All that I have studied have been burned repeatedly, and although the vegetation bears a primitive stamp through the absence usually of introduced plants, one can but guess at the composition and arrangement of the primitive vegetation.

The soil-conditions are different from those of true moor. The ground is frequently ancient coastal terrace, and the subsoil consists altogether of stones which through the presence of "iron pan" are impervious to water. The upper soil consists of clay capped by a layer of peat, usually quite thin, though this may be wanting. Normally, the ground is extremely wet. Where *Leptospermum* does not dominate the covering is a combination of *Cladium teretifolium*, *C. glomeratum*, *C. capillaceum* (at times), *C. Vauthiera*, *Hypolaena lateriflora* and *Gleichenia dicarpa*, just as ordinary peat-moor, in fact. *Lycopodium ramulosum* is abundant, and there may be *Gahnia*-tussocks.

On the pakihis of the North-western district the northern *Epacris pauciflora* is abundant. *Liparophyllum Gunnii*, also common on Stewart Island moor, and *Gentiana Townsoni* are plentiful. The very local *Siphonidium longiflorum* is abundant in places. *Sphagnum* is dotted about in certain parts, but is absent over wide areas, nor does it seem to be making peat. *Leptospermum* at all stages of development is everywhere.

Doubtless the open spaces were once in large part forest, but the native name proves that there was here a primitive moor-association. And yet it is one in which peat was virtually absent!

6. River-bed.

a. General.

River-bed is characteristic of those shingle plains formed by the various streams which still bear their stony burden from the lofty ranges. These beds extend from the sea-coast far into the mountains. Their greatest development is to the E. of the Divide in the South Island, though on the W., although shorter, they are still very considerable. In the North Island, river-bed is much less in evidence.

Between the vegetation of river-bed at different altitudinal belts it is not easy to draw the line; ecological differences are slight, and many species occur throughout. Rainfall is the chief factor that governs the combinations; thus in the South Island the humid W. favours the presence of plants in the lowlands which are purely subalpine in the dryer E.

Terraces[1]) in most places bound the lowland and montane river-beds, while these latter may be 1.6 km in width. It is obvious that as the stony plains themselves have been subject to inundation in all parts during their formation, the vegetation-dynamics of river-bed at the present time must be very similar to that of the plains during their construction.

Typical river-bed consists of a more or less flat expanse of stones which vary considerably in size and are mixed with a large but varying proportion of sand and silt. The river-proper wanders from side to side of the bed in anastomosing streams, its path restricted only by the terraces or adjacent mountains slopes. During the frequent floods, the streams may change their course, so turning stable ground into flood-plain, but rendering the abandoned stony bed fit for plant-colonization. Moreover, the stream may cut into its bed, and terraces, such as now exist far from the river's influence, but whose surfaces are ancient flood-plains, be in process of formation. Thus it can be seen that various associations will exist, each marking a certain phase in the development of the land-surface, commencing with the peopling of the bed as the water recedes, and ending with the vegetation of the oldest flood-plain, the climax-association of the E. being steppe or heath, and of the W. forest.

The ecological conditions are comparatively simple. The stony substratum favours rapid drainage, the water-content close to the surface being extremely small. At a depth of about 30 cm, there is always a certain amount of moisture; the stones themselves assist in reducing evaporation; the sand and silt hold water to some extent; and doubtless the water-table is near enough, even on the highest parts of the bed, to allow deep-rooting plants water in abundance. Were this not so, the extensive plantations of the Canterbury Plains, where the rainfall is low, could not exist. At first, there is a total absence of humus and but little of nutritive salts. When the sky is cloudless, the plants are exposed to an extremely bright light and the stones become burning hot. The wind, hemmed in between terraces, or adjacent mountain-slopes, sweeps over the ground with great force, but its effect is mitigated somewhat by the unevenness of the bed and its larger stones, which afford both shelter and shade. On the E., the hot, dry NW. wind not only causes excessive transpiration, but the course of the river is marked by great clouds of silt and finer sand high in the air. The rain-fall is a factor of moment though much less than in the case of retentive soils nor does it affect the subterranean water-supply, which is regulated by the downpour on the mountains.

In many localities, the vegetation is much altered, especially by continuous thickets of the introduced *Ulex europaeus* and *Sarothamnus scoparius*, but, although various foreign species generally occur where these plants do not dominate, much river-bed is still primitive enough to allow accurate conclusions to be drawn as to its original character.

1) In what follows the South Island is alone dealt with.

Leaving out of consideration the climax-associations (tussock-steppe, heath, forest or scrub), the other river-bed associations contain about 56 species, 1 of which is a low tree, 20 are shrubs, 1 a liane, 25 herbs or suffruticose plants, 8 of the grass-form, 1 of the rush-form and 1 fern.

The principal growth-forms are: — mat-forming plants, often circular; prostrate creeping and rooting herbs; low shrubs often with leafless, green stems, and ericoid-shrubs. *Raoulia lutescens* and *Scleranthus biflorus* are cushion-plants.

b. Unstable river-bed (*Epilobium-Raoulia association*).

Close to the streams, flooding of the surface is too common an occurrence to allow any plant to become established, but where submersion is rare, *Raoulia tenuicaulis* and *Epilobium pedunculare*, thanks to their abundant wind-borne seeds, quickly gain a footing. Both have creeping, rooting stems which hug the ground. *R. tenuicaulis* grows rapidly owing to its mesophytic juvenile- and reversion-shoots; it forms circular, flat, green and silvery patches, 60 cm, or much more, in diam. (Plate XXX, Fig. 40). A few plants of *Raoulia australis* may also be present.

c. Stable river-bed.

The substratum varies considerably according as its surface is stony or silty, the stones, often coated with a dark lichen, may be packed as closely as if paved.

1. Eastern river-bed.

Low, silvery, dense cushions of *Raoulia lutescens* are everywhere, their cushion-form arising from a gradual filling of the plant with wind-borne silt. Great dull-green patches of the shrubby *Muehlenbeckia axillaris* are common, and in the North-eastern and Eastern districts, the leafless, grey-coloured rush-like stems of *M. ephedroides*, of similar habit, may be present. *Raoulia australis*, looser in habit than *R. lutescens*, will be abundant both on silty and stony ground. Somewhat older bed may contain large colonies of *Carmichaelia nana*, its flat, leafless, vertical stems close together and a few centimetres high. The larger, thicker stemmed *C. Monroi*, usually subalpine, may occasionally be present. There will be in the North-eastern and Eastern districts many large irregular patches of *Raoulia Monroi*, distinguished by its folded, silvery, distichous small leaves. Thickets of *Cassinia fulvida* (in the Eastern district) may abound. Low-growing dark-colored, spinous bushes of *Discaria toumatou* will be dotted about or form close masses in which case there is shrub-steppe.

The dying-out of *R. lutescens*, as the vegetation gets thicker, and the plant-covering trapping the blown silt, as well as its decay, leads to a richer and more moisture-holding soil, though still dry enough; tussocks appear and steppe is established. Other common plants of stable stony river-bed are: — *Scirpus nodosus*, *Scleranthus biflorus*, *Crassula Sieberiana*, *Carmichaelia subulata*, *Oxalis corniculata*, *Geranium sessiliflorum* var. *glabrum*, *Epilobium nerterioides*, *Daucus brachiatus*, *Styphelia Fraseri*, *Gnaphalium japonicum*, *G. collinum*, *Cotula perpusilla*.

River-bed dune.

Low isolated dunes, or short ridges, are frequent here and there on river-bed. They are simply collections of the blown sand and silt. Usually they are fixed by vegetation. The small tree *Sophora microphylla* was originally common. *Phormium tenax*, *Arundo conspicua* and *Cassinia fulvida* are abundant. The species of *Raoulia* are generally absent. The introduced *Lupinus arboreus* has complete possession in some localities.

Groves of trees &c.

In some places, even yet, small groves of trees are to be met with, especially at the base of a high terrace. *Sophora microphylla* will be dominant, accompanied probably by *Cordyline australis*, *Pittosporum tenuifolium*, *Melicytus ramiflorus*, *Fuchsia excorticata*, *Nothopanax arboreum* and *Griselinia littoralis*, while *Rubus australis*, *Muehlenbeckia australis* and *Parsonsia heterophylla* may be abundant as lianes loading the trees with greenery.

Phormium-Arundo-Cordyline swamp and slowly-flowing streams or ponds with aquatic and swamp vegetation are common enough on river-beds, but they are identical with similar associations elsewhere and need no description.

2. Western river-bed.

The station is less xerophytic than eastern river-bed and so many of the most xerophytic species are absent, e. g. — *Raoulia lutescens*, *R. Monroi*, the dwarf species of *Carmichaelia*, *Muehlenbeckia ephedroides*, *Discaria toumatou*, *Cassina fulvida* and *Scleranthus biflorus.* Though open in many places, the vegetation may be closed.

The following are the most important species: — *Carex comans*, *Muehlenbeckia axillaris*, *Ranunculus foliosus* (sometimes), *Acaena Sanguisorbae* (var. with silvery leaf), *A. inermis*, *Coriaria ruscifolia*, *C. thymifolia*, *Pimelea prostrata* var. *repens*, *Epilobium pedunculare*, *Hydrocotyle novae-zelandiae*, *Mazus radicans* (very characteristic of Westland river-bed), *Veronica Lyallii* (common in montane belt, but rare at sea-level), *Coprosma rugosa*, *C. brunnea*, *Nertera depressa*, *Wahlenbergia albomarginata*, *Pratia angulata*, *Helichrysum filicaule*, *H. bellidioides*, *Cotula squalida*, *Raoulia glabra* (sometimes), *R. australis*, *R. tenuicaulis.*

3. Western river-terrace scrub.

On older river-bed and on the face of terrace there is in the Western district an association closely allied to subalpine scrub but with the members much more erect and not tangled. The following are the principal species: — *Podocarpus totara*, *Muehlenbeckia australis* (liane), *Rubus schmidelioides* var. *coloratus* (liane), *Carmichaelia paludosa*, *Coriaria ruscifolia*, *Aristotelia fruticosa*, *A. Colensoi*, *Plagianthus betulinus*, *Nothopanax Colensoi*, *N. parvum*, *Pseudopanax crassifolium*, *Griselinia littoralis*, *Veronica salicifolia*, *Coprosma robusta*, *C. propinqua*, *C. rugosa*, *Olearia avicenniaefolia*, *O. ilicifolia*, *O. macro-*

donta, *O. arborescens*, and as undergrowth — *Polystichum vestitum*, *Blechnum vulcanicum*, *B. fluviatile* and *B. penna-marina*.

4. River-bed forest.

This occurs only in the Western district and is in harmony with the climate, which is antagonistic to steppe. The tree-community consists in part of species not common in the adjacent rain-forest, e. g. — *Rubus schmidelioides* var. *coloratus*, *Coriaria ruscifolia*, *Pennantia corymbosa*, *Aristotelia racemosa* and *Plagianthus betulinus*.

The ground is level and traversed by numerous streams. The upper soil consists of humus beneath which is merely river-shingle. The vegetation is in three layers, — the floor-plants, the small tree-ferns and shrubs and the low trees. The association is 4.5—6 m tall and of close growth. Slender tree-trunks not exceeding 15 cm in diam. are the rule; they may be erect or more or less leaning and draped with a moss-mantle while from their branches hangs the pale moss *Weymouthia Billardieri*. *Coprosma rotundifolia*, usually a shrub, is the dominant small tree, and it grows in such profusion at times as to make pure stands. Besides the already-mentioned trees, the following are common: — *Carpodetus serratus*, *Melicytus ramiflorus*, *Fuchsia excorticata*, *Pseudopanax crassifolium* var. *unifoliatum* and *Griselinia littoralis*. Stunted *Podocarpus totara* and *Weinmannia racemosa* may occur.

The second tier consists of young forest-trees, the *Coprosma*-form dominating, together with small *Dicksonia squarrosa* and *Hemitelia Smithii* and the semi-tree-ferns *Polystichum vestitum* and *Dryopteris pennigera*.

On the floor are mosses, liverworts, the liane *Metrosideros hypericifolia* (creeping), *Blechnum capense* and *B. fluviatile*.

The lianes *Rubus schmidelioides* var. *coloratus*, *Metrosideros hypericifolia* and *Polypodium diversifolium* are common, the two latter especially abundant on tree-fern stems. The filmy ferns, *Hymenophyllum scabrum*, *H. sanguinolentum* and *Trichomanes reniforme* cover the leaning trunks, particularly of *Griselinia littoralis*. *Polypodium grammitidis*, *P. Billardieri* and the orchid *Earina mucronata* are fairly common as epiphytes.

At an altitude of some 300 m on river-bed in the Western district there is an association closely allied to subalpine totara forest (Plate XXXI, Fig. 41), although that of the adjacent slopes is *Weinmannia-Metrosideros* and that of swamps *Podocarpus dacrydioides*.

Podocarpus Hallii, *Phyllocladus alpinus* (a tree) and *Pseudopanax crassifolium* var. *unifoliatum* are dominant (Plate XXXI, Fig. 42) and *Libocedrus Bidwillii* sub-dominant. The forest is low, the trees &c. are erect. The undergrowth consists principally of — *Polystichum vestitum*, *Pittosporum divaricatum*, *Aristotelia fruticosa*, *Nothopanax simplex*, *N. anomalum*, *Suttonia divaricata*, *Coprosma rotundifolia*, *C. propinqua*, *Olearia ilicifolia*, *O. avicenniaefolia*. There is also some *Drimys colorata*, *Carpodetus*, *Pennantia*, *Myrtus pedunculata* and *Griselinia littoralis*. *Rubus schmidelioides* var. *coloratus* is the sole liane.

5. North Island river-bed.

My notes on the North Island formation are altogether insufficient. River-bed from the Dividing Range may contain *Raoulia tenuicaulis*, species of *Epilobium* and perhaps thickets of *Cassinia leptophylla*. In the Egmont-Wanganui district *Veronica catarractae* var. *lanceolata* and *Gnaphalium keriense* are characteristic and there may be young shrubs, especially *Carmichaelia australis*, *Coprosma robusta* and *Veronica salicifolia*.

7. Grassland.

a. General.

The natural grasslands of New Zealand, here termed steppe, differ essentially from meadows of the Old World. Green, flat-leaved, turf-forming grasses do not rule, in their stead is brown tussock composed of closely-bunched filiform rolled leaves and slender culms.

Grassland is far more abundant in the South than in the North Island, its presence depending on a drier climate than rain-forest can endure. There is nevertheless evidence that some of the apparently primeval steppe may have been produced through forest fires, a supposition partly based on Maori tradition and partly on the presence of the remains of burnt trees in Central Otago, Canterbury and elsewhere.

Tussock-steppe is no longer virgin. Continual grazing, periodical burning and the presence of numerous well-established introduced plants has brought about no few changes, but these are not sufficient to have obliterated the primitive stamp in many localities, or to have eradicated any species.

The association is wanting in the Northern botanical province; its place being taken by heath. Further S., it occurs in various localities E. of the central mountain-chain and on the higher parts of the Volcanic Plateau. In the South Island, it occupies wide areas on the E. of the Divide being the formation of greatest physiognomic importance. Also, there are considerable stretches in the South Otago district where however the formation intergrades with moor.

In some localities, montane forest which has been destroyed has been replaced by steppe; in other localities much grassland has been converted into artificial pasture of European grasses, or into corn-land.

There are two distinct classes of tussock-steppe, the one (low steppe), in harmony with low rainfall, frequent wind and dry soil, and the other (tall steppe), tolerating a wet, sour soil and high rainfall. Both associations are xerophytic. The tussock itself is closely in harmony with steppe-conditions and can endure the most prolonged and violent winds. When on dry ground, its long deeply-descending roots reach the ground-water, while its numerous short ones passing into the water-absorbing dead leaves at its base can take advantage of even brief showers. Once the tussock gains a footing on the soil, the low-growing mesophytes can settle in the open spaces sheltered from wind. Thus the actual formation depends for its very existence on the tussock, as does a forest on its tall trees.

The species number about 77, leaving out those found only in tall tussock, made up of: — trees and shrubs 10; herbs and semi-woody plants 47; grass-like plants 15; rush-like plants 2; ferns 3.

b. The associations.

1. Low tussock-steppe (Poa-Festuca tussock association).

This plant-community is exceedingly uniform in physiognomy, no matter its altitudinal position. When viewed from a distance, the ground appears clothed with a yellow carpet so smooth and even as to give the impression that all litter had been swept away with some giant broom. Here and there on the hillsides are dimples on its surface marking gullies or depressions. Such apparent smoothness is quite deceptive. Multitudes of tussocks, each some 40 cm high, stand everywhere either close and touching or with spaces between. Here and there are solitary specimens, or clumps of *Cordyline australis* or *Phormium tenax*. In the South Island dark-coloured bushes of *Discaria toumatou* may be dotted about and species of *Carmichaelia*, their green, erect leafless stems 1 m high, are not uncommon. Small, frequently prostrate herbs or low-growing shrubs occupy the spaces between the tussocks. Some of the more common are: — *Danthonia semiannularis, D. pilosa, Agropyron scabrum, Dichelachne crinita, D. stipoides, Carex breviculmis, Ranunculus multiscapus*, species of *Acaena, Geranium microphyllum, Pelargonium inodorum, Oxalis corniculata, Epilobium novae-zealandiae, Aciphylla squarrosa, Hydrocotyle novae-zelandiae, Styphelia Fraseri, Dichondra repens, Convolvulus erubescens, Plantago Raoulii, Wahlenbergia gracilis, Lagenophora pumila, Vittadinia australis, Helichrysum filicaule, Celmisia longifolia* and *Gnaphalium collinum.*

Montane tussock is richer in species, certain plants common at a higher altitude being present. The following assist in modifying its physiognomy at a near view: — *Poa Colensoi, Scleranthus biflorus, Acaena Sanguisorba* var. *pilosa, Pimelea prostrata* var. *repens, Plantago spathulata, Wahlenbergia albomarginata, Brachycome Sinclairii, Raoulia subsericea* and *Senecio bellidioides.* At a varying altitude, say 800 m, the association passes imperceptibly into subalpine steppe, an ecologically and in part floristically similar association.

2. Tall tussock-steppe (*Danthonia Raoulii* association) of Red tussock.

This association occupies the drier of the open lands of the lowlands in the South Otago district, it also extends into Stewart Island. In many cases it follows after *Sphagnum*-moor, and intermediates exist which can be referred to either community. The association is distinctly of a subalpine character owing perhaps to latitude, lack of sunshine, frequent rain, cold winds and sour stoil. The substratum is either peat or clay.

Reddish coloured tussocks of *Danthonia Raoulii* some 80 cm high stand so closely that, in many places, there seems tussock only. But, there are generally spaces, large or small, between the tussock-colonies. In such there may be dark-coloured, entangled, shining masses of the wiry stems of *Gaultheria perplexa*. *Phormium tenax* is common in some places. *Astelia montana* often makes considerable colonies. Other important members are: — *Blechnum pennamarina*, *Herpolirion novae-zelandiae* (especially montane), *Aciphylla squarrosa*, *Gaultheria depressa*, *Pentachondra pumila*, *Styphelia empetrifolia*, *Plantago Raoulii*, *Pratia angulata*, *Oreostylidium subulatum* (especially montane), *Lagenophora petiolata*, *Celmisia longifolia* var., *Craspedia minor* and *Raoulia glabra*.

8. Rock.

a. General.

Rock-vegetation does not play nearly so important a part in the lowland-lower mountain belt as in that of the coast or the high mountains for it is absent over those wide areas, the coastal plains and northern gumlands and is but little in evidence on many of the lower hills. By far its greatest development is in river gorges; near some of the large lakes and in the highest portions of the area, when the associations will be merely a continuation of those at a higher level.

As elsewhere, rock offers most diverse ecological conditions for plant-colonization, but the various associations may be roughly grouped into those of dry and those of wet rocks. As for the chemical composition of the rock, that does not seem of much moment since the same association can occur both on greywacke and limestone, though apparently a few vascular plants [1]) are confined to the latter. Certain species [2]) too are restricted to the volcanic rock of Banks Peninsula, but their presence cannot be explained with reference to the substratum.

The total number of species occurring on lowland-rock throughout is about 175, belonging to 43 families and 95 genera and consisting of, — trees 5, shrubs 53, herbs 61, lianes 9, epiphytes 8, grass-like plants 10, rush-like 1 and ferns 28. Only 20 species are true rock- or semi-rock-plants, and of these, 6 alone are confined to the lowland-lower mountain area. As for the other species they are either forest-hygrophytes which occur on rock within the forest, or in constantly wet stations, or mesophytes or xerophytes belonging to adjacent formations, e. g. — *Muehlenbeckia complexa*, *Coriaria ruscifolia*, *Leptospermum scoparium*, *Styphelia acerosa*, *Veronica salicifolia* and *Helichrysum glomeratum*, to cite a few.

b. Northern botanical province.

The most important rock-plants are as follows: — *Asplenium flaccidum* *Polypodium diversifolium*, *Cyclophorus serpens*, *Blechnum capense*, *Poa anceps*.

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1) *Asplenium lucidum* var. *anomodon*, *Anisotome patula*.
2) *Veronica Lavaudiana*, *Senecio saxifragoides*.

Cladium Sinclairii (often dominant), *Cordyline Banksii*, *Phormium tenax*, *P. Cookianum*, *Astelia Solandri* (often dominant), *Astelia Cunninghamii* var. *Hookeriana* (abundant on old lava flows), *Bulbophyllum pygmaeum*, *Earina mucronata*, *Peperomia Endlicheri*, *Elatostema rugosum* (wet rocks), *Rubus australis*, *Coriaria ruscifolia*, *Leptospermum scoparium*, *Metrosideros diffusa* (sometimes dominant), *M. scandens*, *Griselinia lucida*, *Gaultheria antipoda*, *Styphelia acerosa*, *S. fasciculata*, *Veronica salicifolia*, *V. macrocarpa*, *Nertera Cunninghamii* (wet rocks), *Olearia furfuracea*, *Celmisia Adamsii* (Thames sub-district and near Whangarei), *Gnaphalium keriense* (wet rocks), *Brachyglottis repanda*.

c. Central botanical province.

The coastal tree, *Metrosideros tomentosa*, grows luxuriantly on cliffs of Lakes Rotorua, Rotoiti, Tarawera, Taupo and other lakes of the Volcanic Plateau district as also on cliffs at L. Waikaremoana (East Cape district).

In the East Cape district, rocks in the drip of water are clad with a luxuriant growth of *Jovellana Sinclairii*[1]) and probably wide breadths of *Gnaphalium subrigidum* or *G. keriense*. A very common association throughout in river-gorges is that of *Blechnum capense*[2]), *Cladium Sinclairii* and *Gnaphalium keriense* with shrubs, especially *Veronica salicifolia*, projecting outwards or downwards. On drier rocks, in the full sunlight, the small tuft-tree *Cordyline Banksii* may form close masses accompanied by *Poa anceps* (a most common rock-plant throughout the North Island), *Veronica salicifolia*, *Brachyglottis repanda* and other shrubs.

The vegetation of the soft shale ("papa") cliffs of the many deep gorges of the Wanganui coastal-plain is perhaps the most important rock-association of the North Island and represents, on a vaster scale, that briefly described above, where *B. capense* dominates. Taking the gorge of the Wanganui itself, there are many kilometres of cliff, sometimes sloping and sometimes perpendicular. Above comes low *Beilschmiedia tawa* forest, beneath which there may be a belt of shrubs and beneath this again the true cliff-covering consisting above of masses of the drooping, smooth, flat, pale-green, grass-like leaves of *C. Sinclairii* 1 m or so long by 2 cm wide and great breadths of the huge leaves of *B. capense*, this the physiognomic plant. If the position is specially wet and shaded, pure yellowish-green colonies of *Elatostema rugosum* are characteristic. Nearer the base of the cliff is great abundance of *Gnaphalium keriense* mixed with *Veronica catarractae* and beneath this again *Adiantum affine* with stunted fronds. *Phormium Cookianum* is abundant in places;

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1) Stem creeping and rooting, finally erect, 15—45 cm high; leaves thin, pubescent, long-petioled, ovate with blade 2.5—7.5 cm long; flowers rather showy, white spotted purple.

2) The great pinnate leaves, 90 cm to even 3 m in length, project downwards; each keeps so clear of those adjacent that the whole covering makes an ideal mosaic. These close mantles of *B. capense* are a striking feature of New Zealand everywhere on the banks of moist gulleys and give a most characteristic stamp to the scenery.

Senecio latifolius[1]) is common where the rock is wet and *Euphrasia cuneata* is abundant at lower altitudes.

In the Ruahine-Cook district, the following characteristic plants occur on rock in gorges piercing the high mountains: — *Carmichaelia odorata*, *Jovellana repens* and *Veronica catarractae*. On dry rocks in the open, and this applies to much of the North Island, the following occur: — *Cyclophorus serpens*, *Phormium Cookianum*, *Poa anceps*, *Leptospermum scoparium*, *Styphelia acerosa* and *Brachyglottis repanda*.

d. Southern botanical province.

In the drier parts of the South Island the following species frequently occur on rock no matter its nature: — *Asplenium flabellifolium*, *Polystichum Richardii*, *Gymnogramme leptophylla*, *Dichelachne crinita*, *Danthonia semi-annularis*, *Poa caespitosa*, *Agropyron scabrum*, *Phormium tenax*, *Muehlenbeckia complexa*, *Scleranthus biflorus*, *Crassula Sieberiana, Rubus australis*, *R. cissoides* var. *pauperatus*, *Acaena Sanguisorbae* var. *pusilla*, *A. novae-zealandiae*, *Carmichaelia subulata*, *Geranium sessiliflorum*. var. *glabrum*, *Oxalis corniculata*, *Coriaria ruscifolia*, *Discaria toumatou*, *Pimelea prostrata*, *Leptospermum scoparium*, *Epilobium cinereum*, *Corokia Cotoneaster*, *Styphelia acerosa*, *S. Fraseri*, *Olearia Forsteri* and *Senecio lautus*.

The *Olearia insignis* association, already described for the coast, with a few changes in its composition extends inland up the river-valleys of the North-eastern district to an elevation of about 900 m. The association is equally at home on greywacke and its allied rocks, as on limestone. Inland, the community contains much more *Veronica Hulkeana* and *Senecio Monroi* than does the coastal. In some places *Clematis afoliata*, *Celmisia Monroi*, *Anisotome aromatica* var. and *Wahlenbergii Matthewsii*, are constituents.

The rock-association of Banks' Peninsula is restricted thereto. Its fullest development is on rock facing S. The special plants are: *Veronica Lavaudiana*, *Senecio saxifragoides*, *S. lagopus* and *Celmisia Mackaui*[2]).

Other accompanying species are: *Polystichum Richardii*, *Luzula campestris* var., *Phormium tenax*, *Linum monogynum*, *Angelica Gingidium*, *Anisotome Enysii* or a closely-related species, *Corokia Cotoneaster*, *Griselinia littoralis*, *Styphelia acerosa*, *Veronica leiophylla*, *Celmisia longifolia* and *Olearia Forsteri*. On rocks in full sunshine, *Cheilanthes Sieberi* and *Nothochlaena distans* are common.

There is a rich rock-vegetation at the lower Waimakariri Gorge (Canterbury Plain) consisting of the usual xerophytic shrubs, but of special interest

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1) The allied *S. Turneri* with its long creeping stem and bright-green, cordate leaves 15 cm long with stalks 15—30 cm is conspicuous where it occurs, but so far as known it is of local distribution though extending from the Wanganui to the Mokau River. *Ourisia macrophylla* is also, at times, one of the association.

2) *S. saxifragoides*, so far as I know, is confined to the Port Hills' portion of Banks Peninsula and *S. lagopus* to the rest of the area. The differences between the two are quite technical, the plants being otherwise identical in appearance. *C. Mackaui* has been recorded only from the neighbourhood of Akaroa.

is the occurrence of the usually coastal *Rhagodia nutans* and *Angelica geniculata* and the strongly xerophytic fern *Gymnogramme rutaefolia.*

The vegetation of limestone rocks, North Canterbury, contains amongst other species *Asplenium obtusatum* var. *anomodum*, *Adiantum affine*, *Clematis afoliata*, *Angelica Gingidium* and *Olearia avicenniaefolia.* Limestone in North Otago possesses a scanty vegetation of the *Asplenium* (as above), *A. Hookerianum*, *Epilobium cinereum*, *Anisotome Enysii* and, in the shallow gullies the following shrub-association: — *Cordyline australis*, *Discaria toumatou*, *Melicytus ramiflorus*, *Griselinia littoralis*, *Myoporum laetum* and *Coprosma propinqua.*

On dry rocks in the upper Clutha Valley (North-Otago district) are the following: — *Cheilanthes Sieberi*, *Agropyron scabrum*, *Scleranthus biflorus*, *Rubus subpauperatus*, *Carmichaelia compacta*, *Discaria*, *Hymenanthera angustifolia* var. *alpina*, *Pimelea sericea*, *Myosotis albo-sericea* and *Veronica pimeleoides.*

The rock-vegetation of the W., with its rain-forest climate, differs in many respects from that of the E. On wet rocks in river gorges the following are generally abundant: — *Hymenophyllum multifidum*, *Blechnum vulcanicum*, *Gaultheria antipoda*, *Gunnera albocarpa*, *Nertera depressa*, *Gnaphalium Lyallii*, *G. trinerve* and *G. keriense.* Many stunted trees and shrubs gain the rock as soon as soil is sufficient, so that a close shrubbery will fill the gullies and hollows. *Cordyline Banksii* is common in the North-western district and some parts of the Western. *Jovellana repens* in company with *Gunnera albocarpa* and *Nertera depressa* occurs where water drips over rock in some parts of the Western district.

On limestone at Greymouth there is: — *Cordyline Banksii*, *Asplenium lucidum*, *Polypodium diversifolium*, *Veronica salicifolia*, *Olearia avicenniaefolia* and *Brachyglottis repanda* (on dry ledges) and *Asplenium lucidum*, *Epilobium rotundifolium*, *Lagenophora pumila*, *Craspedia unifolia* var. and *Gnaphalium Lyallii* (where water drips).

Section III.

The Vegetation of the High Mountains.

Chapter I. General Remarks on the High Mountain Vegetation.

1. Floristic Details.

The extremely mountainous character of New Zealand has led to the development of a rich and varied alpine flora, no fewer than 498 species of vascular plants being altogether confined to the high mountains while, in addition, 99 occur in the lowlands under special circumstances only. There are also 348 species which are found both in the lowlands and high mountains so that the alpine flora, as a whole, numbers 945 species as against 998 for the lowlands and lower hills while if the alpine and coastal elements be deducted from the latter the alpine flora exceeds the lowland by 80 species.

If the 99 occasional lowland species be considered as virtually alpine, the high-mountain element of the New Zealand flora will number 597 species belonging to 45 families and 123 genera. No less than 561 of the above species (94 p. c.) are endemic, and, if only the dicotyledons be considered, the percentage rises to 97. The affinities of the remaining species are: — Australian 22, Fuegian 9 and cosmopolitan, or nearly so, 6. The above does not do justice to the Fuegian relationship, since about 35 species, belonging to 35 genera, have near relations in subantarctic South America[1]).

The following 15 genera (7 endemic) and one family are confined[2]) to the high mountain belt: — *Marsippospermum*, *Exocarpus*, *Hectorella*°[3]), *Pachycladon*°, *Notothlaspi*°, *Corallospartium*°, *Swainsona*, *Pernettya*, *Loganiaceae* (*Logania*, *Mitrasacme*), *Phyllachne*, *Forstera*, *Leucogenes*,°) *Haastia*° and *Traversia*°. This does not show anything like the local endemism of the lowland flora with its 15 locally endemic families and 94 genera, but the following two lists bring out more clearly the striking floristic differences between the two floras, and, at the same time, with what has gone before, show the special composition of the high-mountain flora.

1. Genera typically alpine which descend to sea-level, or thereabouts, only under special circumstances: — *Alsophila*, *Cystopteris*, *Triodia*, *Carpha*, *Oreobolus*, *Lyperanthus*, *Adenochilus*, *Caltha*, *Drapetes*, *Schizeilema*, *Archeria*, *Ourisia*, and *Abrotanella*.

2. Characteristic high-mountain genera with the total number of species for each genus in brackets[4]) followed by the number of species confined respectively to the high-mountain and lowland areas: — *Agrostis* (6), 4, 1; *Calamagrostis* (10), 5, 2; *Deschampsia* (5), 3, 0; *Trisetum* (4), 3, 0; *Danthonia* (15), 10, 1; *Koeleria* (3), 2, 0; *Poa* (24), 10, 6; *Carex* (53), 19, 16; *Luzula* (13), 10, 1; *Colobanthus* (9), 7, 1; *Ranunculus* (42), 30, 7; *Radicula* (5), 3, 2; *Geum* (5), 3, 1; *Acaena* (10), 7, 1; *Pimelea* (14), 6, 3; *Epilobium* (38), 15, 9; *Aciphylla* (19), 17, 0; *Anisotome* (16), 11, 3; *Dracophyllum* (23), 14, 2; *Gentiana* (17), 13, 1; *Myosotis* (29), 20, 5; *Veronica* (95), 55, 24; *Ourisia* (11), 8, 1; *Euphrasia* (13), 10, 2; *Plantago* (8), 3, 2; *Lobelia* (3), 2, 1; *Olearia* (39), 14, 18; *Celmisia* (53), 41, 2; *Raoulia* (21), 15, 0; *Helichrysum* (12), 6, 2; *Cotula* (20), 9, 7; *Senecio* (31), 10, 13.

Certain other genera or families, although they contain few or no strictly high-mountain species, play an important part in the flora, e. g. — *Taxaceae*,

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1) Nor do the figures express the Australian-Fuegian relationship, but the matter receives fuller treatment in Part III, Chapter II.

2) Some descend in certain localities into the lower mountain belt.

3) Endemic genera marked thus °.

4) The difference between this number and the sum of the two following numbers of course represents the species common to both areas. With lowland are included coastal.

Hierochloe, *Festuca*, *Uncinia* (5 alpine out of 15 spp.), *Phormium*, *Chrysobactron*°, *Herpolirion*, *Nothofagus*, *Elytranthe*, *Muehlenbeckia*, *Montia*, *Stellaria*, *Drosera*, *Carmichaelia*, *Geranium*, *Oxalis*, *Coriaria*, *Stackhousia*, *Aristotelia*, *Viola*, *Hymenanthera*, *Leptospermum*, *Halorrhagis*, *Nothopanax*, *Hydrocotyle*, *Angelica*, *Corokia*, *Griselinia*, *Gaultheria*, *Styphelia*, *Epacris*, *Archeria*, *Suttonia*, *Rubiaceae*, *Pratia*, *Wahlenbergia*, *Lagenophora*, *Brachycome*, *Gnaphalium*, *Cassinia*, *Craspedia*, *Microseris* and *Taraxacum*.

The headquarters of the New Zealand alpine flora is in the high ranges of the Southern botanical province, for out of the 597 alpine species no fewer than 422 (71 p. c.) are confined thereto. The Central province contains only 174 species, 140 of which are more or less common in the Southern province while 33 are locally endemic and 2 belong to the Northern province. In this latter the small alpine florula of 25 species is confined to the Thames subdistrict where on only one mountain[1]) is there open land containing a mixture of shrubs and herbs.

There is considerable local endemism in the different botanical districts, but no details are given here since the facts are partly dealt with when treating of the formations as also in Part III, Chapter I. Also gradual changes occur in passing from N. to S. but the mountains are not sufficiently explored to warrant detailed statistical treatment.

2. Vertical Distribution (The Belts of Vegetation).

Details regarding vertical distribution are not easy to supply. That most important factor, the winter-snow-line, is obviously correlated with the aspect of the slope, so that alpine species descend much lower on shaded than on sunny faces. Edaphic conditions also contribute their share. Even on forest-clad ranges, many bare patches, containing high-mountain grass or herb vegetation, extend far below the forest-line. Then there is the gradual effect of change in latitude and the differences in distribution on "wet" or "dry"[2]) mountains, as also the many intermediate stages between such extremes. In fact, each mountain supplies its own special circumstances, and, were the details at my disposal far more accurate, only general statements could be made. As it is, one has to trust, in many instances, to estimated heights, so that the details given here, and further on, are essentially approximate.

Commencing at sea-level the belts of vegetation are here styled, — *lowland*, *montane*, *lower subalpine*, *upper subalpine* and *alpine*. Obviously, the boundaries of these differ for each botanical district and also in the districts themselves. The chief delimiting factor appears to be the winter snow-fall. So soon as one reaches that part of a mountain where the snow has lain for

1) Te Moehau (825 m). This mountain is lower than others of the range on which alpine plants are absent and their presence on Te Moehau may be explained by its position with regard to winds antagonistic to forest.

2) These terms are merely comparative. There are no really dry mountains in New Zealand.

some months certain characteristic plants[1]), rare or absent below, appear in force and a new vegetation is encountered. The average winter snow-line then forms the boundary between the alpine and upper subalpine belts and it fluctuates from about 1500 m on the Volcanic Plateau to 1200 m in the North-eastern district and 900 m in Stewart Island.

At a lower altitude, another fluctuating line occurs which marks the point at which snow may lie, at most, for a week or two; this forms the boundary between the upper and lower subalpine belts, and it descends about 300 m below the alpine line. At 300 m below the upper subalpine line comes the lower subalpine denoting the average limit reached by winter snow which either melts at once or remains at most a few days[2]). Below this point the lowland-lower mountain area, already dealt with, is encountered.

Taking the whole high-mountain flora of 945 species, the lower subalpine belt contains 666, the upper subalpine 743 and the alpine 403, about 100 of which occur at the highest altitudes. With regard to the high-mountain species, about 52 do not usually occur below 1200 m altitude, 227 below 900 m of which 35 are confined to between 900 m and 1200 m and 320 below 600 m of which 65 are virtually confined to between 600 m and 900 m though a few may descend considerably lower[3]).

3. Alpine Plants at Sea-level.

As already seen, 99 species of high-mountain plants occur at about sea-level, many of which are most characteristic alpine plants, e. g. to mention a few, — *Carpha alpina*, *Oreobolus pectinatus*, *Gaimardia ciliata*, *Astelia linearis*, *Caltha novae-zelandiae*, *Carmichaelia Monroi*, *Drapetes Dieffenbachii*, *Styphelia empetrifolia*, *Coprosma repens*, *Donatia novae-zelandiae*, *Celmisia argentea* and *Senecio Lyallii*. There is also a second category, the members of which are numerous enough to class also with lowland species, although their distribution may be restricted to a special climate or soil. Such are e. g. — *Podocarpus nivalis*, *Dacrydium Bidwillii*, *Phyllocladus alpinus*, *Astelia montana*, *Carmichaelia grandiflora*, *Coriaria thymifolia*, *Gaya Lyallii*, *Pimelea Gnidia*, *Gunnera dentata*, *Gentiana Townsoni*, *Veronica Raoulii*, *Olearia Colensoi* and river-bed species of *Raoulia*. These lowland-alpine plants fall into three principal classes as follows: — 1) Those which as steppe-plants find a continuous path by means of that formation to the lowlands. 2) Those which descend by means of stony river-bed. 3) Those which are restricted to that part of New Zealand

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1) For instance in the North-western district, *Danthonia australis*, which even on mountains to the E. may fill hollows where snow lies for a long period; in the Eastern district *Celmisia Haastii* and *C. viscosa*; in the Western and parts of Fiord districts, *Danthonia crassiuscula* and *Celmisia sessiliflora*.

2) In exceptional winters snow lies much longer than stated above, but this has no effect on distribution.

3) These heights are supposed to represent an average, they will rise for the North Island and sink for the S. of the Southern botanical province.

possessing a modified subantarctic climate. To the first two classes belong xerophytes of physically dry stations and to the latter bog-xerophytes and subalpine-scrub shrubs. Actual "alpine" associations, and not isolated species only, occur at sea-level, such as those already briefly described in Part II, Chapter IV, under the heading "Rock and Cliff". As to the causes furthering this phenomenon something is said under heading 5 of this chapter.

4. Repeopling the new ground during the Retreat of the Glaciers.

Even today, glaciated New Zealand is not altogether a thing of the past. Leaving out of consideration the great eastern glaciers of the central Southern Alps, a fair idea of what glaciated Westland was like is afforded by the Franz Josef and Fox glaciers with their terminal faces at 211 m and 204 m respectively and distant only a few kilometres from the sea. At the present time, the peopling of the new ground just abandoned by the ice can be observed, together with what has taken place at no distant date, indeed every transition can be plainly seen from bare rock, or moraine a year or so old, to forest. It seems then not unreasonable to conclude that what is happening at the present time is merely a repetition of what occurred throughout the Western botanical district at the conclusion of the New Zealand ice-age. To the E. of the Southern Alps, the process is beclouded, but even there the present plant-colonization of river-bed may be similar to that of the Pleistocene valley-floors. Here, as this latter phase has been treated at some length in other publications[1]), only an account is given of plant-colonization near the Franz Josef glacier at the present time.

Three habitats are being invaded, — rock smoothed by the ice, moraine (both lateral and terminal) and river-bed, the rock being by far the most extensive.

At an altitude of about 300 m, close to the lateral margin of the glacier on the recently abandoned rock, there is no vegetation whatsoever, but, at a few metres distance from the ice, there are everywhere patches large and small some 2—3 cm deep of the moss *Rhacomitrium symphiodon*[2]) which, decaying below, rapidly forms raw humus suitable for germination of seeds. The rock is a quartzose schist marked by numerous cracks, grooves or notches running parallel with the glacier. So soon as the moss has prepared a soil these chinks are invaded by vascular plants (Plate XXXIII, Fig. 44), the "seeds" brought by wind from the neighbouring scrub and forest or carried on the rock-surface by water. More than 30 species of pteridophytes and spermophytes take part in the invasion, but the most important are, — *Hymenophyllum multifidum* (grows on solid rock and forms soil), *Lycopodium varium*,

1) COCKAYNE, 1911 c.; and SPEIGHT, COCKAYNE and LAING, 1911: 343—345.

2) The leaves, when wet, are spreading and hold abundance of water in their axils; when dry, they are erect and pressed closely to the stem. The plant clings to the rock with great tenacity.

Calamagrostis pilosa, *Poa novae-zealandiae*, *P. Cockayniana*, *Schoenus pauciflorus* (especially where water lies), *Earina autumnale*, *Carmichaelia grandiflora*, *Coriaria ruscifolia*, *Metrosideros lucida*, *Gunnera albocarpa*, *Gaultheria rupestris*, *Dracophyllum longifolium*, *Veronica subalpina*, *V. Lyallii*, *Coprosma rugosa*, *Celmisia bellidioides*, *Olearia avicenniaefolia* (almost the first-comer), *O. ilicifolia*, *O. arborescens*, *O. Colensoi*. The transforming of rock, thus occupied, into a closed association is a very slow process, so that there are many extensive bare patches of considerable age. Where moraine, even if quite thin, is deposited upon the rock, a closed association is quickly produced. Thus Harper Rock, a roche moutonnée still partly embedded in the terminal face of the glacier, is quite bare except on the summit where, on a patch of moraine, there is an embryonic scrub of *Arundo conspicua*, *Carmichaelia grandiflora* and some other plants.

On older moraine-covered rock, at some distance back from the rock now being invaded, is a broad belt of tall scrub consisting of the shrubs already mentioned (subalpine-scrub species) together with rain-forest species, especially, — *Asplenium bulbiferum*, *Blechnum lanceolatum*, *Polystichum vestitum*, *Histiopteris incisa*, *Carpodetus serratus*, *Weinmannia racemosa*, *Melicytus ramiflorus*, *Fuchsia excorticata*, *Coprosma lucida* and *Coprosma foetidissima*. Within, is more or less *Metrosideros lucida*, i. e. the association is potential Southern-rata forest. Such an association forms the next belt which extends upwards perhaps to the scrub-line and marks a comparatively recent advance of the ice.

According to Bell, "probably not more than 150 years ago"[1]), the glacier extended 820 m northwards down the valley, depositing on its retreat extensive terminal moraines. On these, and the old river-bed, can be seen vegetation at different stages of formation, the climax, so far, being a scrub about 3.6 m high (Plate XXXIII, Fig. 45). On older moraine still, there is *Metrosideros lucida* forest but the climax-association of the valley is taxad-forest with *Dacrydium cupressinum*, *Podocarpus ferrugineus*, *P. Hallii* and the ordinary trees, shrubs, tree-ferns[2]) and ferns of the Western district rain-forest.

At the greatest extension of the glaciers in the Pleistocene period, both on the extreme E. and W. of the Southern Alps, there would be peaks and slopes, not necessarily of great altitude, free from ice and still harbouring the Pleistocene alpine flora many of the species of which we may conclude were identical with, or closely resembled, those of today. But as such havens of refuge would be of limited extent, the struggle for existence would greatly reduce the number of species. Some certainly, if the glacier-extension were due to elevation of the land and not to increased cold[3]), would migrate on to the Canterbury Plain &c., where, under intensified steppe conditions, they

1) A Geographical Report on the Franz Josef Glacier, Wellington, N. Z., 1910: 5.

2) *Hemitelia Smithii* also occurs in the forest above the glacier.

3) The presence of a tree-fern, *Hemitelia Smithii*, in one valley of the Lord Auckland Islands, is a pretty sure sign, as Speight has pointed out to me, that the ice-period of that group was not due to increased cold.

would, as DIELS was the first to point out, assume more xerophytic structure and the xeromorphic growth-forms (the divaricating, flat-stemmed leafless, cupressoid &c.) have arisen, while on the eastern mountain-slopes the drought-conditions would be still more severe and sufficient to have evolved the great *Raoulia* cushions. With the retreat of the glaciers on the W., as the bare rocks of the slopes disintegrated, they would be readily colonized in the wet climate by the neighbouring plants, just as is happening now, while forest would by degrees advance from the coastal-plain to the river-valleys. On the E. the struggle between disintegration and plant-occupation would be far more severe, the plant-covering nevertheless increasing slowly in area. This struggle still goes on, river-fans in particular exhibiting every stage of occupation, destruction and rejuvenescence of their plant-covering. But now man as an agent of destruction has appeared and he is rapidly undoing the work of thousands of years, and has already converted much of Central Otago into veritable desert!

5. The ecological Conditions of the High Mountains.

High mountains the world over are subject to a set of similar and fairly definite conditions which there is no need to discuss here. On the other hand, those specially affecting New Zealand need brief mention, so far as they are known or suggested.

No accurate details are available regarding the high-mountain climate. It s clear however that the species are not attuned to nearly so great intensity of cold as are alpine plants in general. This is clearly brought home by the fact that many species of the alpine belt cannot endure the winter temperature of Kew and hardly any that of Berlin. Probably — 18° C. is more than most can endure. Certainly, a protecting snow-covering stands for a good deal, but many species tolerate equally well snowy and snowless stations (e.g. — *Veronica pinguifolia* (agg.), *V. epacridea*, *Aciphylla Monroi*) while many of the less hardy shrubs are never completely buried.

The amount of rain and the yearly number of rainy days is much greater than in the lowlands, while, in addition mist and cloud[1]) are frequent. The abundance of vegetation at above 800 m in Central Otago, below which altitude the induced desert gradually appears, clearly confirms the above statement. But it must not be concluded that in an extremely wet climate xeromorphic plants are an anomaly. On the contrary, too much stress cannot be laid on the effect of short periods of drought. A few fine days in the extremely wet Western botanical district will dry up streams one might well believe to be permanent, even if they occur on fairly level ground, and make the surface so dry that one has to be most careful regarding fire. Where the soil is extremely porous, as on the Volcanic Plateau, during a specially dry period

1) Often cloud covers the lower portions of the mountains only, in which case the alpine belt is exposed to strong insolation.

plants such as *Celmisia spectabilis* may be killed by drought. In short, many species obviously depend far more upon precipitation than upon ground-water and, in this regard there is a similarity between rain-forest and herb-field.

The N.W. rain, on which depends the distribution of many formations in the South Island, is a warm snow-melting rain, whereas that from the S.W. is cold and generally terminates in snow, succeeded by frost. This latter rain, in South Otago and Stewart Island is a most important factor towards inducing herb-field and moor. Its frequent occurrence, combined with cloudy skies, brings in those subantarctic conditions which even in the lowland favour alpine plants. On the slopes of the Southern Alps facing the Canterbury Plain and on the Seaward Kaikoura Mts. much rain comes from the E.

Snow is a most important factor in New Zealand high mountains. It has been already shown how the primary division of the vegetation into belts depends upon the winter snow-fall. The amount that collects in gullies &c. must be very great. When the upper mountains are almost bare, at the end of January or later, in the Western, Fiord and South-Otago districts, great masses at times resembling glaciers still lie in cirques and gullies. Snow-avalanches are extremely frequent, even on the driest mountains, and their effect is indeed great in destroying vegetation and furthering denudation (Plate XXXV, Fig. 47). In the alpine belt the vegetation after the snow has melted looks just as if a steam-roller had passed over the surface, so flattened to the ground are the plants. The effect of temporary streams and pools, or of snow-water in hollows, is reflected by the presence of special species and combinations of plants. The mechanical effect of a heavy snow-covering upon the subalpine-scrub may be pointed out, but it alone is not responsible for the peculiar growth-forms.

The wind-factor is of great moment, acting as it does both mechanically and physiologically upon the plants, while as an agent of denudation it is of considerable importance. Hemmed in between the high ranges, bounding narrow valleys, the power of the wind attains great intensity. Bare ground is frequently impossible to populate with plants when swept at intervals by furious gales. The N.W. wind of the South Island is of peculiar ecological significance. But for its prevalence, there would be forest where tussock-steppe at present rules. When this wind, a true foehn, rages, and the sky is cloudless, under a burning sun transpiration must reach its maximum.

The plants themselves once established modify both climate and habitat so greatly as to make their own conditions. For instance, though soil be the same and climate the same, in the first instance, the ecological circumstances of fell-field, herb-field, forest and scrub are quite dissimilar. The burning of *Nothofagus*-forest or subalpine-scrub may at once bring replacement by tussock-steppe, or dominance of *Phormium Cookianum* respectively, associations ecologically distinct from the original. The subantarctic characteristic of a plant's dead parts turning into peat while still attached to the living plant itself is strongly developed in many alpine genera (*Phyllachne*, *Celmisia*, *Raoulia* &c.) and plays an important part in modifying the habitat.

Topographical changes are of course of prime importance both with regard to the evolution of vegetation and species. At the present time, the great prevalence of mountains composed of greywacke and allied rocks which supply débris in enormous quantity leads to the constant establishment of migratory formations both progressive and retrogressive. Although such formations are from their nature transient, yet they are constantly being re-established, so that they present permanent habitats where habitat-effects can accumulate and new species arise. Disintegration of the surface-soil, the result of wind, snow, frost and rain action, is always in progress, especially where steppe-conditions prevail, so that the surface is not even like a meadow but there are low raised mounds of vegetation surrounded by sunken bare patches. Many other details as to habitat-ecology are cited when dealing with the formations.

Chapter II.

The leading Physiognomic Plants and their Growth-forms.

1. Forest Plants.

a. The Species of Nothofagus (Plate XXXIX).

Nothofagus is a subantarctic genus confined to southern South America, New Zealand, Tasmania and eastern Australia. The New Zealand species, 6 in number, are all endemic. *N. cliffortioides* is the most important mountain species. It varies epharmonically from a tree 6—15 m high to a stunted spreading gnarled shrub. As a tree, (its general growth-form), it possesses a usually straight trunk, 20—60 cm in diam. covered with moderately smooth bark about 4 mm thick. Where not crowded, the tree is most symmetrical with its numerous wide-spreading branches to its base which branch abundantly in a more or less distichous manner. Within the forest, the trunk is bare for its lower half or two-thirds and the upper branches, though dense enough, are much contracted. The final twigs bear, on their flanks, the numerous hard, stiff, coriaceous, small, glossy, dark-green, ovate leaves which are clothed beneath with white adpressed hairs. The distichous arrangement of branchlets and leaves gives the appearance of close horizontal layers of foliage one above the other. The flowers are monoecious, the staminate being extremely abundant, and, when a tree is in full bloom, quite showy from their red colour. The species, except in certain parts of the North-western and Fiord districts is confined to the mountains. It is abundant in the Central and Southern provinces, but neither it, nor any of the genus extends to Stewart Island. *N. Solanderi* so closely resembles *N. cliffortioides* as to need no description. It is a taller tree, however, and lowland or montane rather than subalpine.

Nothofagus Menziesii, when lowland or montane, is a tall and massive tree, but in the subalpine belt it approximates to *N. cliffortioides* in size, and like it may occur merely as a shrub. The trunk is frequently buttressed at the base. The bark is, at first, thin and silvery, but eventually becomes furrowed. The head of the subalpine tree is small and open; the branches are frequently gnarled. The leaves are small, coriaceous, rather thick, bright-green, but yellowish in the mass and broadly ovate with crenate margins; on the undersurface are fringed domatia. The species differs from all its New Zealand congeners in its glandular involucre which places it nearer the Tasmanian *N. Cunninghamii* and the Fuegian *N. betuloides*. It occurs from the Thames Mountains to Foveaux Strait from sea-level to the subalpine belt.

Nothofagus fusca, in the lowlands, is a still larger tree than *N. Menziesii*. It ascends only to the montane and lower subalpine belts. The trunk is frequently 2 m in diam., covered with deeply furrowed bark and furnished at the base with massive plank-buttresses. The leaves are rather thin, 2.5 cm or more long, broadly ovate, bright-green and deeply serrate. North of the Auckland Peninsula, the species occurs most sparingly as far N. as Kaitaia, but is abundant in the Central and Southern provinces.

The remaining species *N. Blairii* and *N. apiculata* are of limited and local distribution and need no special mention.

b. Libocedrus Bidwillii Hook. f. (*Pinac.*) *Pahautea*; *Cedar*.

Libocedrus Bidwillii is an evergreen conifer which hardly attains to more than 12 m in the subalpine belt, but is frequently of smaller dimensions. The trunk, covered with pale chestnut-coloured loose flaking bark, is remarkable straight and often some 54 cm in diam. The upper third of the tree consists of a dense, tapering conical head made up of short branches and leafy twigs forming somewhat horizontal layers. Adult and juvenile shoots are distinct, the latter having a row of flattened acute leaves some 3—4 mm long on each flank, and an inconspicuous upper and under row of quite minute appressed triangular leaves, the short branchlets looking like fern-pinnae. The ultimate shoots of the adult are tetragonous, 1.5 mm in diam. and their leaves closely appressed, triangular and minute. The species occurs on Mounts Te Aroha and Egmont, the Volcanic Plateau and the Dividing Range in the North Island and throughout the South Island in many parts of the mountain areas.

c. Phyllocladus alpinus Hook. f. (*Taxac.*) *Mountain toatoa*.

Phyllocladus alpinus varies from a small tree some 7 m high with a trunk about 25 cm in diam., covered with a moderately smooth blackish bark to d shrub 1—2 m tall. The branches are numerous and stout; they finally giva off many flexible straight, opposite branchlets which are naked for their lower half or third and then give off cladode-bearing stems. The cladodes, which exactly resemble leaves, are numerous, frequently arranged in threes, moderately close, patent or semi-vertical, pale-green, waxy beneath, thick, coriaceous, oblong to rhomboid in shape and variable in size. The flowers are monoecious. Seedlings bear true leaves, narrow-linear in shape and such occur on older plants as reversion-shoots, especially on stems near wet ground. The species is abundant in mountain forests and scrubs from the Thames Mountains to Foveaux Strait and descends to sea-level in the W. of the South Island.

d. The two species of Gaya (Malvac.), Mountain ribbonwood.

There are two species of *Gaya*, *G. Lyallii* and *G. ribifolia*, which are of similar habit but differ somewhat in the flower, and especially in the leaf, that of the latter being less hygrophytic than that of the former. This is reflected in their distribution, *G. Lyallii* occurring only where there is a rain-forest climate and *G. ribifolia* where there is a steppe climate. Both are small deciduous trees 4—6 m high, usually much branching from near the base and of a rather twiggy habit. The bark is smooth, pale-coloured and may be peeled off in long strips. The leaves are dimorphic; they vary from the lobed, more or less orbicular juvenile to the but little hairy cordate adult of *G. Lyallii* furnished with a drip-point, and the broadly ovate adult, still faintly lobed, with truncate base and almost tomentose under-surface of *G. ribifolia*. The bright green colour of the leaf of *G. Lyallii* resembles that of European deciduous trees; that of *G. ribifolia* is paler. The flowers of both species are large, white, showy, abundant, and not unlike cherry blossoms. Both species are confined to the Southern province. *G. Lyallii* grows in both forest and subalpine scrub and *G. ribifolia* in terrace-scrub or it forms small groves.

2. Scrub Plants.

a. The shrubby Compositae. — Olearia, Senecio, Traversia.

Tall composite-shrubs, or even small trees, are one of the most striking features of the subalpine belt; their form, the frequently grey colour of the foliage, and, in due season, the abundant flower-heads rendering them conspicuous. The plants in question belong to the genera *Olearia*, *Senecio*[1]) and the endemic monotypic *Traversia*.

With the exception of two species of *Olearia* of the divaricating form and the rock-inhabiting *O. insignis*, all the composite-shrubs have the same growth-form. This consists of a generally quite short trunk from which radiate upwards and outwards at about an angle of 45° stout, stiff branches, which, branching several times, 2 or 3 branches passing off in close proximity, a close, wide, leafy head is formed. As development proceeds, the lower branches in large measure die and are cast off, so that the shrub is quite open below, but above consists of a rounded mass of dense, short twigs the outer being leaf-bearing. As a rule, the leaves are coriaceous, hard, thick and densely

1) *Olearia* is restricted to New Zealand, Tasmania, Australia and Lord Howe Island. The New Zealand species number 40, all of which are endemic. Of these 21 are found in the subalpine belt, 13 of which are purely mountain plants. *Senecio* contains 18 New Zealand and endemic shrubby species 9 of which occur in the mountains, 6 of these hardly descending below the subalpine belt.

tomentose beneath. All are simple, but there are marked specific distinctions in size and shape [1]). Several species attain the stature of small trees with stout, frequently semi-horizontal trunks, from which hang long strips of papery bark (Plate XL, Fig. 59) e. g.: — *Olearia ilicifolia, O. macrodonta, O. arborescens, O. avicenniaefolia, O. excorticata, O. lacunosa, O. Colensoi, Senecio elaeagnifolius.*

b. Divaricatingly-branched shrubs (Plate XXXV Fig. 48).

The divaricating growth-form consists of much-branched, stiff, wiry, sometimes flexuous stems closely pressed together and interlaced, the branching being frequently at, or about, a right angle. There is considerable variation from great rigidity to extreme flexibility. As already seen, the form occurs abundantly in many lowland formations, but it is also characteristic of montane and subalpine river-bed and terrace scrub. Taking the whole New Zealand region, the growth-form occurs in 16 families, 21 genera and 51 species, 23 of which ascend to the mountains [2]). Although, in some cases, it is not possible to refer this striking physiognomic and biological form to habitat-conditions, in many instances the relation is obvious, and a most notable example of convergent epharmony is afforded.

Besides growing in dense masses on river-terraces &c., these shrubs also occur isolated, or in small clumps on stony ground where they appear as dark patches.

c. The shrubby species of Veronica [3]) (*Scrophular.*).

A quite narrow belt which lies between 600 and 900 m altitude with some extension in either direction is the special home of many shrubby species of *Veronica*, especially in the steppe-climate of the Southern Province. Two growth-forms, the "ball-like" and the "cupressoid" are of great physiognomic and biological importance in this class of shrubs. In the first instance, all the species are built on the same plan. A number of stout straight stems radiate symmetrically upwards and outwards at a narrow angle from a common base. Above, these branch abundantly decussately at an angle of about 45°, the peripheral twigs being green, slender, rather succulent and covered closely with

1) Some species have leaves more than 10 cm long and others less than 2 cm. Oblong in various combinations is the common form, but linear occurs in 3 species. *Senecio cassinioides* has dimorphic leaves; the adult are linear to linear-oblong and but 5 mm long. *Traversia* has glabrous thin leaves.

2) The following are the most important mountain species: — *Pittosporum divaricatum, Sophora prostrata, Discaria toumatou, Elaeocarpus Hookerianus* (juvenile only), *Aristotelia fruticosa, Hymenanthera dentata* var. *alpina, Corokia Cotoneaster, Suttonia divaricata, Coprosma rugosa, C. cuneata, C. parviflora, C. depressa, C. ciliata, Olearia virgata.*

3) New Zealand contains 86 shrubby species of *Veronica*, and this is a low estimate, only 1 being non-endemic. 53 species occur in the mountains only 7 of which descend to the lowlands. With regard to their determination, in many cases, it is not easy to assign a name that can be understood, except by the giver. Many of the commonest species are undoubtedly made up of unnamed segregates, and other forms may be hybrids. However, physiognomically and even biologically such close distinctions vanish.

leaves. In many cases, the equality of growth in all directions leads to a remarkable ball-like form, so that bushes perhaps 1.5 m high and 1 m through look as if they had been trimmed by a gardener's hand [1]. The roots do not descend deeply but form a mat near the surface, any stem in contact with the ground readily forming adventitious roots. The ball-like form is well-suited to combat strong winds, and may be considered a xerophytic adaptation. The leaves are either patent or sub-imbricating; they are but few centimetres long, moderately thick, sessile, nearly glabrous, coriaceous and vary both in the species and in individuals in the ratio between length and breadth [2].

The cupressoid-veronicas have scale-like reduced leaves pressed so tightly to the stem as to be almost on the same plane as the bark. In outline they may be more or less rounded, but the absence of spreading leaves makes the growth more open. Juvenile plants have thin, flat, pinnatifid, spreading hygrophytic leaves. This class of *Veronica* numbers 15 species at least all of which are subalpine or alpine.

The only other class of *Veronica* needing mention here consists of quite low-growing shrubs with conspicuous thick, more or less imbricating glaucous leaves and prostrate or subprostrate gnarled often black stems. Such play a part in the physiognomy of stony alpine slopes and dry rocks. The number of distinct forms is manifold, but most are included under the conceptions *V. pinguifolia*, *V. carnosula* and *V. Buchanani*. The green-leaved *V. decumbens* also comes under this head, in which, as in many of the glaucous forms, the leaf-margins are stained red.

The flowers of the veronicas are in racemes, or spikes of different lengths or, in the cupressoid forms, in small heads. They are produced in great abundance. White, pure or more or less deeply tinged with lilac, is the prevailing colour [3]. In some species the flowers are sweet scented.

d. *The species of Dracophyllum* (*Epacrid.*).

There are 26 [4] species of *Dracophyllum* for the whole New Zealand region, all of which are endemic. Eighteen occur in the montane, subalpine or alpine belts, 10 being purely mountain plants. The genus is confined to New Zealand, Australia including Tasmania (10 spp.) and New Caledonia (5 spp.).

No shrubby plants play a more distinguished physiognomic part in the mountain scenery than the species of *Dracophyllum*. On slopes 600 m, or

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1) To this category belong *Veronica buxifolia* var. *odora*, *V. Traversii*, *V. monticola*, *V. subalpina*, *V. leiophylla*, *V. Cockayniana*, *V. laevis*.

2) Seedling leaves differ from adult in that they are petiolate, more or less deeply toothed, thin in texture and ciliate on the margins. They occur also on reversion-shoots.

3) The various forms of *V. pimeleoides* are bright blue; *V. Raoulii* clear lilac, *V. elliptica* (coastal) blue fading to white, *V. latisepala* (lowland) various shades of violet and purple.

4) CHEESEMAN (1906, pp. 418—428) admits only 18 species. The difference between his estimate and mine arises from my considering most of his varieties species.

more, above the observer, it is easy to pick out, by their brownish colour, those spots which betray the presence of one or other species of the genus, and one conversant with plant-combinations can thus gain a fair idea of what plants occupy that particular station. Subalpine scrub, too, with *Dracophyllum* present, at once differentiates itself from that where the genus is absent. Some of the species are small trees, others medium-sized shrubs, and one, *D. politum*, forms under certain conditions massive cushions (Plate XXXVI, Fig. 49).

The erect shrubby species have a special growth-form, the chief characteristics of which are: — stiff, erect stems of a more or less fastigiate habit; branching at a narrow angle and vertical, needle-like leaves, sometimes of considerable length, with sheathing bases.

D. Traversii, abundant in the upper subalpine forest or tall scrub of the North-Western and Western districts, is a small tree, varying from 9—3 m in height, with an erect trunk 60—25 cm in diam. covered with smooth, reddish-brown bark which scales off in papery flakes. At about its upper fourth, the trunk gives off a few very stout branches, which, curving outwards and upwards and branching 3—4 times in candelabra-fashion, bear on their ultimate stems great rosettes of reddish leaves. These are thick, coriaceous, 30—60 cm long and 5 cm wide at the base; they taper gradually into extremely long, fine points. The inner leaves of the rosette are not fully developed and erect and overlapping, but the outer spread out radially and are strongly recurved, the long points hanging downwards [1]).

D. recurvum of the Volcanic Plateau is of extreme physiognomic importance in that locality. It is a much-spreading prostrate shrub forming rounded reddish open cushions, or patches, of much-branching rigid stems covered with dark bark and bearing, on the peripheral twigs, semi-rosettes of narrow, stiff, recurved, tapering leaves 2.5 cm long.

3. Plants of Steppe, Herb- and Fell-Field or related Formations.

a. The species of Celmisia (Compos.). — Plates LI, LII, LIII.

Celmisia in the New Zealand region contains 51 species; all, except *C. longifolia* agg. are endemic, and with the exception of *C. vernicosa* and *C. campbellensis* occur on the mountains of the North, South and Stewart Islands; *C. longifolia* in many places, and two or three others under special circumstances, descend to the lowlands. The degree of variation in many species, both germinal and environmental, is extreme, making classification difficult and uncertain; in no few instances it is doubtless epharmonic and a manifest epharmony distinguishes certain species.

Celmisia is the dominant genus of New Zealand mountains above the forest-line. Go where you will on subalpine and alpine herb- or fell-field and the silvery foliage of the species strikes the eye, it may be in stately rosettes of

1) *D. latifolium* and *D. Townsoni* have the same growth-form as here described, while *D. Menziesii* of the Fiord district and Stewart Island possesses it in miniature (Plate XXXVII, Fig. 50).

dagger-like leaves, in circular mats trailing over the ground or in dense cushions. Their aromatic fragrance fills the air; from early till late summer some of their white heads of blossom may be seen, while, in due season, gregarious species clothe both wet herb-field and dry, stony slopes with sheets of white.

The following characters, with but few exceptions, are common to all the species. They are suffruticose rather than herbaceous, since the stems are more or less woody, and the leaves persist throughout the winter. The leaves are stiff coriaceous and crowded, rosette-fashion, at the extremities of the stems to which they are attached by broad sheaths, the outer enclosing the inner and the whole forming a terete, stem-like mass; or they are arranged spirally along the branches their sheaths tightly overlapping; the under-surface is densely clothed with tomentum which varies much in character in different species, being silky, woolly, cobwebby, kidglove-like &c.; the upper surface is often covered with a silvery pellicle; the sheaths remain attached to the plant long after the blade has decayed, and, as a wet, rotting mass, enclose the stem. The roots are stout, long and cord-like.

There are three distinct varieties of the *Celmisia*-form. — 1. The leaves are long, the innermost upright and the outer often more or less recurved above making a large semi-erect rosette; the branches of the stem are short so that the rosettes stand closely together and form a circular mass[1]).

2. The stems are prostrate, much branching and put forth adventitious roots at intervals. The leaves are shorter than in the foregoing class, the rosettes, if the leaves are sufficient crowded to form such, less erect and the plant forms wide circular mats or trails over the face of rocks or banks[2]).

3. When the stem branches so frequently as to bring the rosettes into very close proximity a cushion may result, especially when abundant peat is formed within the plant from its dead parts[3]).

Celmisia ramulosa is a true shrub some 15 cm high with erect or semi-erect branches which are leafy from base to apex. The leaves are very numerous, close-set, patent, slightly recurved and broadly linear and the margins are so much recurved as almost to conceal the under-surface.

b. Aciphylla Colensoi Hook. f. and its allies (*Umbell.*), *Spaniard*; *Taramea.*

Aciphylla Colensoi is extremely common on the mountains of the South Island on tussock-steppe and fell-field. In the North Island it occurs on the Ruahine Mountains.

The growth-form recalls that of certain species of *Yucca* rather than of one of the Umbelliferae. Each individual forms an upright circular mass of erect, stiff, hard, bayonet-like leaves from the centre of which arises the extremely stout flower-stalk furnished with bracts resembling the leaves in

1) Examples are: — *C. coriacea, C. Monroi, C. Lyallii, C. pseudo-Lyallii, C. Petriei, C. Armstrongii, C. lanceolata, C. petiolata, C. rigida, C. Traversii, C. verbascifolia, C. spectabilis.*

2) Examples are *C. incana, C. discolor, C. intermedia, C. Lindsayi, C. Walkeri, C. Sinclairii, C. rupestris, C. Gibbsii.*

3) Examples are *C. laricifolia, C. Hectori, C. sessiliflora, C. argentea, C. linearis.*

miniature, in the axils of which are small umbels on stout, short, branched pedicels. Average plants have a diameter of about 86 cm and a height of 50 cm. The leaves are yellowish green, 30—60 cm long and so stiff, thick and rigid as to be almost motionless in a heavy gale; they are pinnate or bi-pinnate with leaflets 6 cm or more long terminating in sharp, stiff, long spines. The rootstock is quite short and the plant is firmly anchored by means of a very long, flexible, rather fleshy, deeply-descending tap-root. The plants are dioecious and the inflorescence of the staminate plant more lax than that of the pistillate.

Fig. 51. *Ranunculus Lyallii* in herb-field near source of R. Rakaia at about 1200 m altitude, Southern Alps, Western district. Photo M. C. Gudex.

Although apparently so well equipped against the attacks of grazing animals, the species is in danger of extinction in many places. Formerly veritable thickets made travelling, even on horseback, impossible over certain parts of the montane steppe. But at the present time sheep eat the flower-heads within their reach, and, in winter, rabbits and hares devour the roots. The plant has a natural enemy, too, in a certain species of beetle.

The allied *A. maxima* is much larger in all its parts than the above; when in flower it is a striking object. It frequently grows in subalpine scrub. *A. conspicua* occupies a similar station. It is distinguished by its bright orange midrib and bracts.

c. The large-leaved species of Ranunculus.

There are 9 species of *Ranunculus* with large leaves and strikingly handsome flowers, some of which in certain localities occur in sufficient quantity to dominate the landscape.

The famous mountain lily, *R. Lyallii*, is the most noteworthy (Fig. 51; Plate XLIV, Fig. 63). It is confined to the Southern botanical province and is common on the wetter western mountains from the S. of the Spenser Mountains to Stewart Island. The Western district is its headquarters. It forms colonies many square metres in extent to the almost complete exclusion of all other plants. Each individual consists of a very large fleshy, broad, thick rhizome furnished with abundant descending stout, flexible roots. As the plant grows, one end of the rhizome decays while the apex increases in length, the plant thus slowly occupying new ground. From the apical end of the rhizome, long-petioled, peltate leaves are given off, the petioles vertical and the blades horizontal, thus effectively shading the ground beneath. These leaf-blades are smooth, bright-green, flexible, coriaceous and frequently form a concave saucer-like surface which is filled with water after rain. The petioles are stout; they measure 30 cm or more in length and the blade may be 24 cm, or more, in diam. The flowers, borne on tall branched stalks, rise high above the foliage. They are pure white, the petals at times so numerous that the flower looks semi-double, and 30 blossoms to a stalk, each 7 cm in diam., are quite usual. It may easily be seen, then, what a glorious spectacle is a hillside clothed as far as the eye can see with close colonies of this noble plant! Nor is it when in bloom alone that it is striking, for, when not in flower, the great leaves, almost knee-deep, show more plainly their unusual form. In March and April, the leaves die down, fresh ones appearing in October and November, by the end of which month a few flowers appear on plants at 900 m altitude in the Western district. The commonest habitat is fairly well-drained, rather deep soil on subalpine herb-field exposed to full sunshine, but it also grows well in shady places where soil has accumulated on uneven rocks and in open places in subalpine scrub. The rhizome is usually close to the surface of the ground and its upper part above the soil. Seedling-leaves are reniform, and these may persist in adult flowering plants. *R. lobulatus* and *R. Traversii* have occasionally peltate leaves.

In the North-western and Ruahine-Cook districts *R. insignis* occupies a similar place to the above. The flowers are golden-yellow, 4—5 cm in diam. and each tall flower-stalk may bear 12 blooms or more. The leaves are dark-green, glossy, somewhat coriaceous, rounded-cordate and about 15 cm in diam.; their petioles are stout and some 16 cm long.

R. Buchanani grows in great abundance in the alpine belt of the Fiord district. So far as vegetative parts go, it is much smaller than either of the above, but the white flowers, solitary or 2—3 together, are 6 cm in diam. The leaves are reniform, 8—10 cm in diam. and deeply cut with narrow segments.

R. Godleyanus is confined to the Western district. The flowers are yellow, borne on a stout stem and 5 cm in diam. The leaves are broadly oblong, the blade 8 cm or more long and the petiole rather shorter[1]).

1) Other handsome species are: — *R. nivicola* (Mt. Egmont and Central Plateau); *R. sericophyllus* (many parts of Southern Alps); *R. Baughani* (Fiord); *R. Matthewsii* (Fiord) perhaps hybrid; *R. lobulatus* (North-eastern); *R. Haastii* (Single-slips of dry S. Island Mts.)

d. *The species of Raoulia* (*Compos.*).

The genus *Raoulia* is endemic; it contains 22 species which are separated into the subgenera *Eu-Raoulia* and *Psychrophyton*. Fifteen of the species are confined to the mountains, the remainder, though also montane or subalpine, descend to sea-level. Four species occur in the North Island, one being confined thereto, but the remainder are found only in the Southern province.

The species are either patch-(frequently circular) or cushion-plants, but the growth-forms are constructed on the same plan, intermediates between them occur and the difference is merely one of degree. There is a central woody main stem and a deeply-descending chief root. From near the base of the main stem rooting prostrate branches pass off radially. These branch abundantly, the branches tending to grow upwards, while frequent branching and consequent increasing density hinders their horizontal extension. Such closeness of growth, shutting off the light, causes the death of all the interior leaves and many of the stems, the interspaces becoming filled in the case of the thicker cushions with peat from their own decay, and in that of low cushions and patches with wind-blown silt &c. According to the relation between horizontal spread and vertical growth, so are patch-plants or cushions produced. The leaves are small, generally more or less imbricating and frequently tomentose. The ultimate shoots are in some species pressed so closely together that they form a hard unyielding surface as in the case of those immense cushions, the "vegetable-sheep" (*R. eximia*, *R. Buchanani*, *R. Goyeni* &c.). In these, large quantities of peat accumulate in the interior and the upper branches put forth adventitious roots by means of which the plant gets most of its water and salts.

The species of *Raoulia* show an epharmonic gradation of forms from the rapidly growing silvery mats of *R. tenuicaulis*, with its open mesophytic leaves of seedlings and reversion-shoots, to the highly differentiated, dense, woolly masses of the vegetable-sheep[1]), denizens of wind-swept and, at times, sun-scorched alpine rocks.

e. *Gentiana corymbifera* T. Kirk (*Gentianac.*).

G. corymbifera is a noble plant which lights up the rather desolate montane and subalpine steppe with its multitudes of large delicate white flowers. From the centre of a rosette of short yellowish green leaves rises up a stout, yellowish, smooth unbranched peduncle, some 40 cm high, which bears on its summit an umbel or cyme 15 cm or more in diam. of white flowers each 2.2 cm in diam. The species is confined to the drier mountains of the Southern botanical province.

f. *Schoenus pauciflorus* Hook. f. (*Cyperac.*).

Wet or boggy ground in subalpine steppe can be recognized at quite a distance through the presence of *Schoenus pauciflorus* which bestows a distinct reddish hue to the association marking it off from the surrounding grass-tussock.

1) *Haastia pulvinaris*, a plant of equally great dimensions and similar in growth-form to *R. eximia* is also known as "Vegetable-sheep". (Plate XLVIII, Fig. 71.)

The plant itself consists of a bunched-up mass of close, erect, stiff but slender terete, grooved stems, 30—50 cm high, and more or less purplish-red in colour. It is abundant throughout the high mountains of the Central and Southern provinces, ascending to 1500 m and occasionally reaching the lowlands.

g. *The species of Ourisia* (*Scrophular.*).

Ourisia, a genus of about 22 species, is confined to subantarctic South America, New Zealand and Tasmania. The New Zealand species number 11; all are endemic. The three large-leaved species are alone of physiognomic importance, though the remainder are floriferous and showy.

O. macrophylla is especially abundant on the North Island mountains. There is a thick, semi-terete, half-buried rhizome by means of which the plant is capable of rapid vegetative increase and forms wide colonies. At short intervals, leaves are given off from the flanks of the rhizome so closely as to touch. The blades are ovate, crenate, rather thick, vivid green above, but purplish-red beneath and concave, so that they collect water which finds its way to the rhizome by means of the deeply channelled, stout, fleshy leaf-stalk. The flowers are in about 8 whorls on stout peduncles 25 cm high; each measures about 1.6 cm $\times$ 2.5 cm, they are white on the lips but citron-yellow in the corolla-tube.

O. macrocarpa of the Fiord district and *O. calycina*, a closely allied species, or variety, of the central Southern Alps are ecologically similar in form and habitat to *O. macrophylla*, but the flowers are somewhat larger.

h. *Senecio scorzoneroides* Hook. f. (*Compos.*).

In many parts of the wetter high mountains of the Southern botanical province *S. scorzoneroides* plays as great a part in the floral physiognomy as *Ranunculus Lyallii* and many hectares of virgin herb-field in the Southern Alps may be white with the abundant blossoms of this plant. Not only does it grow in the best soil of the hillside, but, in a more stunted form, it thrives on dry rock-faces, consolidated débris-fields and the wind-swept sour mountain-moor of Stewart Island. The leaves, which are summer-green only, are in erect rosettes from a stout root-stock; they are some 15 cm long, broadly lanceolate, moderately thick and glandular-pubescent. The flower heads are in corymbs on tall peduncles, each head being 6—8 cm in diam.[1]) and the ray-florets long. There are two types of flower-head, — one where the rays are not very close, so that the head is star-like, and the other where they are much closer. Further, there are distinct strains of colour, viz: — yellow, white, cream-coloured and lemon.

i. *Chrysobactron Hookeri* Colenso (*Liliac.*).

Chrysobactron Hookeri is very conspicuous through its multitudes of golden-yellow flowers when in full bloom. It has increased greatly with the settlement

1) *Senecio Lyallii* is a much smaller plant and not nearly so conspicuous; its flower-heads are always yellow.

of the country, since owing to its perennial subterranean tuberous roots it can reappear after burning, while also its leaves are not eaten by sheep &c. It occurs from the Volcanic Plateau and Kaimanawa Mountains to Foveaux Strait, both in the lowlands and mountains. The variety *angustifolia* is the prevalent form of the South Island steppe. In Stewart Island there is the allied *C. Gibbsii.*

The plant has a short rootstock and tuberous roots. The leaves are tufted, linear, grass-like, rather fleshy, brownish-green, 30 cm, or so high. The scape is slender 30—60 cm high and bears a raceme some 10 cm long of bright-yellow hermaphrodite flowers about 8 mm in diam. on short, slender pedicels.

Chapter III. The Biology of the High Mountain Plants.

1. Growth-forms.

Here not only the 597 virtually high mountain plants are dealt with but also some others, frequently lowland also, which play so important a part in the vegetation that they cannot be neglected[1]).

a. Trees.

There are 24 trees all of which are frequently shrubs also, while the tree-composites generally belong to this latter class; with the exception of 2, all are evergreen. Although, as lowland trees, 1 species is tall and another of medium height, in the high mountains, generally speaking, all are low only 3 at times exceeding 9 m and the remainder being generally less than 5 m in height.

With regard to their growth-forms, — 3 are canopy-trees; 2 tuft-trees: 9 composite-trees; 6 bushy-trees; 1 of conical form; 1 of araliad-form and 2 of straggling form. Well-marked dimorphism is exhibited by 6 species, the adult and juvenile forms being quite distinct.

Decrease in stature in relation to increase in altitude[2]) is a most characteristic feature of the mountains, so that a species may commence as a tall forest-tree and end as a typical shrub of the subalpine-scrub.

The tree-trunks are generally slender and rarely more than 30 cm in diam. They are also frequently gnarled and at times twisted[3]).

Gaya Lyallii, *Metrosideros Parkinsoni* and *Phyllocladus alpinus* have frequently the main stem decumbent and rooting at the base. The tree-com-

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1) e. g., — *Hymenophyllum multifidum, Phyllocladus alpinus, Podocarpus nivalis, Danthonia Cunninghamii, Phormium Cookianum, Gaya Lyallii, Aciphylla squarrosa, Ourisia macrophylla, Coprosma parviflora, Helichrysum bellidioides, Senecio bellidioides* &c.

2) Exposure to wind and weight of snow are also factors that must be taken into account.

3) This is common with the slender trunks of *Leptospermum scoparium* on a Stewart Island mountain.

posites, forming much of the upper subalpine forest in the Western district, have generally their trunks bent near the base and extending more or less horizontally. In 3 species the bark is fairly thick, but in the remainder it is thin, and in the tree-composites, *Dracophyllum Traversii* and *Libocedrus Bidwillii*, the outer bark hangs in long strips. As with the lowland trees, the species are surface-rooting, but the roots do not extend so far laterally nor are they raised to the same extent above the ground.

Coming now to the leaves, — 23 species have simple leaves, 1 compound, 4 narrow, 2 cupressoid, 17 broad, 2 very large (over 20 cm long), 14 medium (5—10 cm long), 4 small (2.5—5 cm long), 4 very small (less than 2.5 cm long), 22 thick or coriaceous, 2 thin, 12 glabrous, 10 tomentose, 2 more or less hairy. *Olearia lacunosa* has stiff, thick, narrow leaves something after the manner of juvenile *Pseudopanax crassifolium*, with a prominent midrib beneath, from which pass off at a right angle stout lateral veins making sunken interspaces which are filled with thin, rusty tomentum. *O. ilicifolia* has waved margins to the leaves furnished with spinous teeth. In a number of species the leaf-buds are specially protected, 12 having bud-scales, 9 tomentose buds and 1 the bud in a hollow of the leaf-base.

b. Shrubs.

Besides shrubs proper, here are included some of the trees, already treated of, since, in shrub-form, they play too important a part to be overlooked[1]). The number of shrubs dealt with is 177 of which 134 are spot-bound, 43 wandering[2]), 28 tall (3 m or more), 46 medium (1—3 m), 103 low (less than 1 m) of which 37 are very low indeed. About 28 may be considered mesophytes or at most sub-xerophytes and 149 xerophytes in at least 31 of which the xerophily is intense.

The growth-forms of the species and the number of each are as follows: — Divaricating-form 14 (also 1 as a cushion); bushy-form 28; cushion-form 14; prostrate-form 46 (creeping-rooting 39); cupressoid 16 (also 2 as prostrate-rooting); araliad-form 3; ball-like 11; composite-shrub-form 25; *Dracophyllum*-form 7; straggling or spreading-form 7; leafless-form 4 (also 1 as cushion and 3 as creeping-rooting); tuft-shrub 2 (1 tree-fern with prostrate trunk).

The branches and twigs of the shrubs may divided into: — Wiry or stiff 62; twiggy 75 and moderately stout 28. The dense cushion-plants, and some others, fall into none of the above classes. The maximum of rigidity is reached in *Corallospartium*, *Carmichaelia Petriei*, *C. Monroi*, *C. humilis* and

1) Ecologically, the different growth-forms of a species may be of far greater moment than are related species of the same growth-form. For instance, the erect bushy-shrub and prostrate rooting forms of *Leptospermum scoparium* are much more different vegetation-entities than are the ball-like species of *Veronica* most of which could fill one another's places without affecting the association in the slightest degree.

2) Although these terms express most important distinctions, it is not feasible to draw a hard and fast line, for certain "spot-bound" species may wander at times. Where this occurs to a limited extent the species is here classed as "spot-bound", e. g., — the cushion species of *Raoulia*.

Hymenanthera dentata var. *alpina*. Wiry, generally slender stems are characteristic of the divaricating-form; stiff slender stems of the *Dracophyllum*-form; twiggy stems of the shrubby species of *Veronica*, and fairly stout, rather brittle stems, covered in the younger parts with tomentum, of the shrub-composites. The only truly spinous shrub is *Discaria toumatou* (also lowland and coastal), but both *Hymenanthera dentata* var. *alpina* and *Aristotelia fruticosa* produce branchlets spinous at the apex under extreme xerophytic conditions, whereas in the forest, the latter is a twiggy, densely leafy mesophyte. Some of the prostrate species of *Veronica* have extremely tortuous stems.

Deeply descending roots are a common feature, especially in small, spot-bound shrubs. Obviously, shrubs with creeping rooting stems have less need for long roots. Adventitious roots are readily produced on stems of *Veronica*, *Gaya Lyallii*, *Phyllocladus alpinus* and a few other plants, if they come in contact with the moist ground. The peat-forming cushion-plants give off many adventitious roots from their ultimate branchlets which penetrate the moist peat.

The leaves of the high-mountain shrubs are all simple except 3 and may be characterized as follows using the same scale of size as before: — Very small 101 (i. e. with the 9 leafless 62 p. c. of the species); small 50; medium 15; large 1; very large 1; coriaceous or thick 158; thin 16; glabrous 134; hairy 43 of which 34 are tomentose on the under-surface; grass-like 8; cupressoid 20; glaucous on one or both surfaces 12; deciduous 3.

Many of the species exhibit a strong heterophylly and in some cases have distinct growth-forms in the juvenile and adult stages, early leaves being generally mesophytic. Although by no means confined to the following, in them the phenomenon is strongly developed: — The *Taxaceae* excepting *P. nivalis*, *Pittosporum divaricatum*, the species of *Carmichaelia*, excepting *C. grandiflora*, *Aristotelia fruticosa*, the species of *Hymenanthera*, *Discaria toumatou*, *Pseudopanax lineare*[1]), *Nothopanax simplex*, *Dracophyllum longifolium* and some other species of the genus, all the cupressoid forms of *Veronica* and many of the other species, most of the species of *Raoulia*, the cupressoid forms of *Helichrysum*.

c. Lianes, epiphytes and parasites.

Climbing plants are of little moment in the mountain forests and scrubs. *Clematis australis*, *C. marata* and *Rubus schmidelioides* var. *coloratus* alone ascend into the subalpine belt. All are more or less xerophytic; the leaves of the species of *Clematis* are much cut, especially those of *C. marata* where the leaf-surface is much reduced; those of the *Rubus* are of the characteristic type with only prickly midribs in part, the lamina is coated with wax on the under-surface. Not only does *Clematis australis* climb over the subalpine scrub, but it occurs in the steppe-area, in the open, trailing over extremely stony ground.

1) This is of special interest since the long, narrow juvenile leaves much resemble those of *P. crassifolium*, but they are never deflexed, a striking characteristic of those of that species, but are held erect; the juvenile form persists for many years.

There are none of the herbaceous or woody epiphytes in the mountain forests excepting a few ferns, but there is abundance of mosses, liverworts and lichens which owe their position to their ability to tolerate desiccation and, in some cases to store up water. The most interesting fern is *Hymenophyllum Malingii*[1]) generally epiphytic on *Libocedrus Bidwillii*, often on dead trees or decaying parts of living ones, but it occurs also on *Dacrydium intermedium* (PHILLIPS TURNER 1909: 3) and perhaps on *Podocarpus Hallii.*

Four woody parasites gain the mountain belt, — *Tupeia antarctica* which occurs on *Gaya ribifolia* in the lower subalpine area, *Korthalsella clavata* which occurs on certain of the divaricating shrubs of the steppe-area, and *Elytranthe flavida* and *E. tetrapetala* which, as fair-sized shrubs, are abundant on *Nothofagus*. The ecology of all these species has been already briefly described in Section II, Chapter III of this part.

The orchid *Gastrodia Cunninghamii* parasitic on the roots of certain forest plants is the sole herbaceous parasite but it also has been dealt with.

A number of indigenous rusts affect some of the alpine species, but they have hardly been studied as yet; *Clematis*, *Ranunculus*, *Epilobium*, *Olearia Celmisia* and *Senecio* are some of the genera affected.

d. Herbs and semi-woody plants including aquatic species.

The species here dealt with number 500 of which 153 are wandering, 347 spot-bound, 12 annual or biennial, 32 summergreen, 468 evergreen, 77 semi-woody and 423 herbaceous. With regard to the height of the species 4 are very tall (more than 90 cm), 12 tall (60—90 cm), 55 of medium height (30—60 cm), 138 small 15—30 cm, 199 (39 p. c.) very small (less than 15 cm) and 92 closely hug the ground or at most are 3 cm tall.

About 191 species may be considered mesophytes or subxerophytes and 309 xerophytes, in 65 of which the xerophily is intense.

The following are the growth-forms represented, together with the number of species in each: — 1) Annuals or biennials (12), — tufted-grass 2; tufted-herb 6; rosette-herb 3. 2) Perennials (488), — a) Wandering (153) — α) Semi-woody: — mat-form 30[2]), of which 4 form circular mats[3]); turf-making form 2; erect-branching 1. β) Herbaceous: — mat-form 68, consisting of, — fern-mat 4

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1) The leaves are narrow, more or less pendulous and 3—15 cm long. They are opaque and reddish or silvery in colour, through a dense covering of stellate hairs hiding the parenchyma, which does not form a flat leaf-surface but consists of glove-finger-like papillae surrounding the pinnately-branched leaf-nerves. The spaces between the papillae form a richly-developed capillary system shut off from the outer air by the hairy covering. Thus the outer surfaces of the chlorophyll-containing cells are in contact with water unless during the most exceptional occurrence of a protracted drought.

2) This form consists of prostrate stems creeping usually on the surface of the ground and rooting; they put forth shoots which form a more or less close mat of stems and leaves, e.g, — spp. of *Acaena*.

3) Circular mats such as those of *Celmisia Sinclairii* are closely related to flat open cushions. Several of the other species included under the term "mat" occur as circular mats.

(filmy-fern 3), grass-mat 4; rush-mat 2 and herb-mat 58; turf-making form 17[1]), consisting of, — grass-turf 10, rush-turf 2 and herb-turf 5; rosette-herbs 20; tufted-form 8 including, — tufted-grass 5, tufted-rush 1 and tufted-herb 2; *Iris*-form 2; water-plants 5[2]) including rush-form 2, myriophylloid-form 2 and mat or sometimes cushion 1.

b) Spot-bound (335). α) Herbaceous (291): — tufted-form 63 including tufted fern 3, tufted-grass 56; tufted-rush 1 and tufted-herb 3; tussock 18 including grass-tussock 16 and rush-tussock 2; rosette-form 120 of which 27 are erect; cushion-form 52 including grass-cushion 5 and moss-like cushion 14, earth-orchid form 11; erect-branching-form 13; prostrate-straggling-form 9; mat-form (non-rooting) 3; *Iris*-form 1; *Utricularia*-form 1. β) Semi-woody (44): — tufted-fern 2; rosette 6; *Yucca*-form 2; cushion-form 15; erect-branching 11; erect-unbranching 4; mat 4.

The leaves of the high-mountain semi-woody plants and herbs may be characterized as follows: — very large (over 20 cm long) 5; large (10—20 cm long) 33; medium (5—10 cm long) 54; small (2.5—5 cm long) 212, very small (2.5 cm and less in length) 196 which with the small are 61 p. c. of the whole; thin (including non-coriaceous and those not distinctly thick) 185; coriaceous, thick or fleshy 315 (63 p. c.) of which 20 are exceedingly thick, coriaceous, stiff or fleshy; glabrous 360 (72 p. c.); hairy 140 of which 64 are distinctly tomentose on the under-surface.

Dark-colored, brownish or even blackish leaves are a frequent feature of alpine herbs and indeed of New Zealand herbs in general, as in *Gunnera prorepens* of lowland moor, but I can give no approximate statistics. In some cases, I have proved the colour to be dependant at any rate in part on light-intensity, but in other cases this is not the case for the stain is on the basal sheltered portion of the leaf as in some species of *Cotula*. Dull reddish or purplish leaves belong to the same category. Glaucous leaves occur in some species, e. g. — certain *Gramineae*, *Ranunculaceae*, *Acaena*, *Umbelliferae*, *Compositae* &c.

The subantarctic character of dead vegetative parts remaining attached to the living plant and turning into peat is extremely common amongst New Zealand alpine plants and occurs in all degrees of intensity. In the case of *Celmisia* the rotting leaf-sheaths, sopping-wet, are more bulky than the living sheaths that they surround. In the peat-filled cushion-plants the water-holding capacity is very great indeed and the plants are quite independent of soil-water. Many of the steppe-grasses have also a sheathing of dead leaf-sheaths, but these are usually of a drier character than those described above. Living leaves with channelled petioles frequently function in conducting water to the roots as may be seen in certain species of *Ourisia* and *Ranunculus*. The

1) In "turf" there are subterranean rhizomes as a rule and the growth is more even and denser than in "mat" but there are forms which might go into either class.

2) These have been already dealt with as lowland plants, where they rightly receive their place as a distinct class.

great peltate leaves of *Ranunculus Lyallii* are often filled with water after rain, but whether such is absorbed to any extent is not known. Ecologically they function in strongly shading the partially buried rhizomes and in preventing occupation of the ground by other plants. Filiform leaves with rolled margins are characteristic of the steppe grasses. Amongst the more remarkable are *Poa acicularifolia* and *P. pygmaea*, both cushion or semi-cushion plants, those of the former more or less than 15 cm in diam. and those of the latter 5—10 cm. The leaves of the *P. acicularifolia* are about 8 mm long, strongly involute, stiff, curved, smooth and terminating in a sharp point; those of *P. pygmaea* are rigid, coriaceous, folded and frequently not more than 4 mm long. Another remarkable grass is *Danthonia pungens* of Stewart Island. This forms large patches of tufted culms from a woody root-stock bearing the somewhat distant sub-imbricating leaves which are not erect but stand out obliquely; they vary in length from more than 30 cm to 5 cm or even less and are extremely stiff and coriaceous, thick, pale-green marked with brown and taper gradually to a sharp truly pungent apex; the blade is equitant, striated and waxy on the upper surface; the leaf-sheaths are long, about 9 mm broad at the base in large examples and they persist attached to the plant, slowly rotting, and holding much moisture.

The roots of the class of plants under consideration are, in no small degree, in harmony with the station. Thus extremely long roots are more common in plants of rock, stony débris, steppe and fell-field than elsewhere. In some cases, roots do not descend deeply but spread laterally, at times, more or less parallel with the surface. The length of roots of different species growing side by side appear to differ considerably, but I have not sufficient observations to go into this important matter in detail.

2. Pollination.

As elsewhere in the book the matter of pollination can receive only the most superficial treatment. Though butterflies are scarce in the mountains, as elsewhere, there are abundance of Diptera, moths and beetles, so that there is no lack of insects for pollination purposes. Furthermore, the frequent high winds must carry the pollen long distances. The alpine plants, in general, bear abundance of seed. It is true that seeds are more plentiful some years than others, but climate here is the controlling factor with which both abundance of flowers and insects are correlated.

Taking into account only the 597 truly high-mountain species and putting aside the 118 ferns, *Cyperaceae* and *Gramineae* &c., the total to be dealt with is 479 species of which the flowers of 62 p. c. may be considered monoclinous and those of 38 p. c. more or less diclinous (dioecious 55 spp., monoecious 2, heterogamous *Compositae* 128), but these figures are to some extent misleading, since protandry and protogyny are common phenomena.

About 70 p. c. of the species here being dealt with possess fairly attractive flowers, but those of the remainder are generally both dull in colour and very small. The attractive flowers are of the following colours: — white 249 (about 70 p. c.), cream 7, yellow 74, green 1, blue 2, lilac 2, red 2, rose 2, pink 3, crimson 1, black or brown (stamens golden) 2. The attractive flowers belong in large part to the following families or genera: — *Ranunculus*, *Epilobium*, *Aciphylla*, *Ericaceae*, *Epacridaceae*, *Gentiana*, *Myosotis*, *Veronica*, *Ourisia*, *Euphrasia*, *Campanulaceae*, *Stylidiaceae*, *Olearia*, *Celmisia*, *Senecio* and some other genera of the *Compositae*. Many flowers are of a size quite disproportionate to the tiny plants that produce them and in some instances they are in such profusion as to hide the foliage, especially in small cushion plants (Plate XXXVIII, XLIX, Figs. 52, 72). Speaking generally, the floral display of the high-mountains is far more striking than that of the lowlands and the coast. A corrie, one sheet of the dazzling white of *Ranunculus Lyallii* or *Senecio scorzoneroides*, the great mats of *Leucogenes Leontopodium* on the Tararuas (Plate L, Fig. 76) far surpassing the famed Swiss edelweiss, or the Mount Egmont steppe with *Ourisia macrophylla* and the golden *Ranunculus nivicola* in full bloom are sights not readily forgotten.

Regarding scent, perhaps 22 p. c. of the species are sweet-scented. In some cases the flowers may be inconspicuous, e. g. — *Stackhousia minima* (lowland-subalpine) fills the air with delicious fragrance when in full bloom, its tiny yellow flowers close to the ground not visible at first glance.

3. Dissemination.

The question of how the species migrate for long distances is of greater moment with regard to the high-mountain vegetation than for that of the lowlands since the local isolation is much greater. If the true alpines are alone considered only 7 p. c. possess succulent fruit attractive to birds, while 23 p. c., including the ferns, are specially suited for wind-carriage. If to the above be added those plants with hooked fruits (*Uncinia*, *Acaena*), and the earth-orchids with their minute seeds, the total percentage rises to 36. But there are many more species with disseminules attractive to birds or that may readily become attached to them, so that fully 50 p. c. may be widely distributed by means of wind or birds, leaving an equal number unsuitable, under ordinary circumstances, for such methods of dissemination. In the lowland-alpine species the number suitable for long-distance dissemination is greater, 20 p. c. being adapted to bird- and 28 p. c. to wind-carriage.

Speaking generally of dissemination, wind is a most powerful agent, not merely in carrying anemochores through the air, but in blowing disseminules over the ground. The conditions of fell-field and pumice-steppe in this regard are not unlike those of a dune-area. Light fruits or seeds, such as those of *Aciphylla* and *Anisotome*, will be moved by quite a gentle breeze, but there are none that can withstand a gale that hurls small stones and gravel through the air. Run-off water functions strongly as an agent of dissemination and it must play a greater part than wind in closed associations. Snow-avalanches are of considerable moment. A number of birds frequent even the highest mountains and they will transport many seeds &c. which though having no special adaptations for that end may adhere to their feet or plumage, in fact it seems probable that the bird is in large measure responsible for the plant-covering of such an isolated mountain as Mt. Egmont[1]). Seeds such as those of *Veronica* can hardly travel from one mountain-range to another by any other means.

4. Seasonal changes.

If only the upper subalpine and alpine belts be considered, the period of blooming cannot extend much longer than 3 months for any locality and within that space of time many species flower and ripen their fruits, but taking New Zealand, as a whole, it commences about the second week in November and lasts to the end of March, the earliest area being the North-eastern district, and the latest the Fiord district. The same species comes into activity at different times according to its altitude and its relation to sun, shade and the melting of the snow-covering. Thus, the seasonal changes in a snow-filled cirque may be identical with or even later than those at a much greater altitude. The relation of seasonal change to insolation is most marked, e. g. the same species will bloom some weeks earlier in the steppe-area of Canterbury than on the mountains exposed to the western rain-fall a few kilometres distant. Generally speaking, the earlier part of the three months is defined by the greater blooming of herbs and the later part by that of shrubs and the fruiting of the early flowering herbs. During April and to a lesser degree in May, the majority of the trees and shrubs are either ripening or still carry their fruit. Almost as soon as the snow has melted, or even before it is quite away, some species come into bloom, e. g., — *Caltha novae-zelandiae*, *Ranunculus Buchanani*.

Amongst the first species to come into blossom are the following: — *Chrysobactron Hookeri*, *Nothofagus cliffortioides*, *Elytranthe tetrapetala*, *Colobanthus acicularis*, *Ranunculus Lyallii*, *R. lobulatus*, *R. Enysii*, *R. novae-zealandiae*, *R. multiscapus*, *Notothlaspi rosulatum*, *Acaena sanguisorbae* var. *pilosa*, *Geranium sessiliflorum* var. *glabrum*, *Oxalis magellanica*, *Discaria toumatou*, *Viola Cunninghamii*, *Anisotome aromatica*, *Aciphylla squarrosa*, *Myosotis Goyeni*, *Veronica Raoulii*, *V. leiophylla*, *Ourisia macrophylla*, *O. caespitosa*, *Raoulia lutescens* and *Cotula pyrethrifolia*. During December in the Western district the herb-field is in full bloom in the middle subalpine belt, *Ranunculus Lyallii* accompanied by *Ourisia calycina* and *Anisotome Haastii* being reinforced by the middle or end of the month by various species of *Celmisia*, e. g., — *C. coriacea*, *C. Armstrongii*, *C. petiolata*, *C. intermedia* and *C. spectabilis*, some prostrate shrubs, especially, — *Veronica vernicosa*, *Coprosma ramulosa* and *C. serrulata* and various inconspicuous herbs, inter alia, — *Hierochloe Fraseri*, *Poa pusilla*, *Uncinia fusco-vaginata*, *Caladenia Lyallii*, *Caltha novae-zelandiae*, *Drosera Arcturi*, *Epilobium chlorae-*

1) *Puffinus tenuirostris* nests in deep holes on lava slopes on the volcanic plateau. *Charadrius obscurus* is very common right on the mountain summits of the Southern Alps and on the scoria slopes of Ruapehu &c. Even the common sea-gull, *Larus dominicanus*, during the breeding season is found far inland.

folium, *Ourisia sessiliflora* and *Forstera sedifolia.* On the Tararua Mts during the last week in December ASTON noted as blooming (1910a: 13 et seq.), — *Phormium Cookianum*, *Caladenia bifolia*, *Pimelea Gnidia*, *Drapetes Dieffenbachii*, *Aciphylla conspicua*, *Veronica buxifolia*, *Forstera Bidwillii*, *Celmisia hieracifolia*, *C. spectabilis*, *Leucogenes Leontopodium* and *Abrotanella pusilla*. On the Waimarino plain (Volcanic Plateau district), at the same time as above and earlier, there are blooming in the tussock steppe or moor, — *Herpolirion novae-zelandiae*, *Stackhousia minima*, *Aciphylla squarrosa*, *Wahlenbergia albomarginata* and *Celmisia longifolia*.

During January, on the northern and central Southern Alps, the greater part of the shrubs are in full bloom, some having commenced to blossom by the end of December, and the subalpine scrub is lit up by the large cherry-like blossoms of *Gaya Lyallii*, the innumerable sweet-scented flower-heads of the shrub-composites[1]), especially, — *Olearia ilicifolia*, *O. macrodonta*, *O. nummularifolia*, *O. avicenniaefolia*, *Senecio Bidwillii* and *S. elaeagnifolius* and various species of *Veronica* (*V. salicifolia*, *V. subalpina*). During January, many of the species of the Volcanic Plateau, at an altitude of 1000 m and upwards, are flowering freely and by the end of the month the majority are in bloom including such characteristic species as, — *Pimelea buxifolia*, *Epacris alpina*, *Dracophyllum recurvum*, *Veronica laevis*, *V. Hookeriana*, *V. spathulata*, *Ourisia Colensoi* and *Euphrasia tricolor*. At the same season flowering is at its height on other North Island mountains when, according to locality, such important physiognomic plants are in full bloom as, — *Ranunculus insignis*, *R. nivicola*, *Pimelea Gnidia*, *Gentiana bellidifolia*, *G. patula*, *Veronica Astoni*, *Ourisia macrophylla*, *Celmisia glandulosa*, *C. spectabilis*, *C. hieracifolia*, *Helichrysum bellidioides* var. *prostratum*, *Leucogenes Leontopodium* and *Cassinia Vauvilliersii*. By the middle of January, the vegetation of Mt. Anglem (Stewart District) is quite as much advanced as in the N. owing probably to its lower altitude and the insular character of the climate. Quite 80 p. c. of the florula is in bloom including *Chrysobactron Gibbsii*, *Aciphylla Traillii*, *Dracophyllum politum*, *Veronica Laingii*, *Celmisia argentea* and *C. linearis*.

During February, the floral display of the high mountains continues, the shrubs are at their best in the early part of the month, herbs which at a lower altitude are in fruit are blooming in the alpine belt, so that in one place or another examples can be seen of nearly all the alpine flowers. The seeds of a few species are already ripe, e. g. — *Uncinia uncinata*, *Ranunculus Lyallii*, *R. Buchanani*, *Epilobium pedunculare*, *E. glabellum*, *Anisotome filifolia*, *Styphelia empetrifolia*, *S. Fraseri* and *Cotula pyrethrifolia*.

Even so late as the first two weeks of March, flowers are still be seen in certain localities especially in the Fiord district where *Carmichaelia grandiflora*,

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1) The extremely floriferous *Olearia arborescens* is the earliest species to flower and in some localities its blossoms are opening by the end of November. On the other hand, *O. moschata* is in full bloom on the Takatimu Mts (South Otago district) at the beginning of March.

Ourisia macrocarpa, *Celmisia verbascifolia* and other plants still blossom. Various species of *Gentiana* are also late or long flowerers and their season extends to the beginning of April. But generally speaking, the flowering season is over and the herbs have ripened their seeds. By the end of the month many of the shrubs are loaded with fruit and, at this stage, species of *Coprosma* covered thickly with translucent drupes are objects of great beauty. On river-beds of the Southern Alps, *C. brunnea* forms strings of shining beads in every shade of blue. Throughout April and early May, there are still many berries,

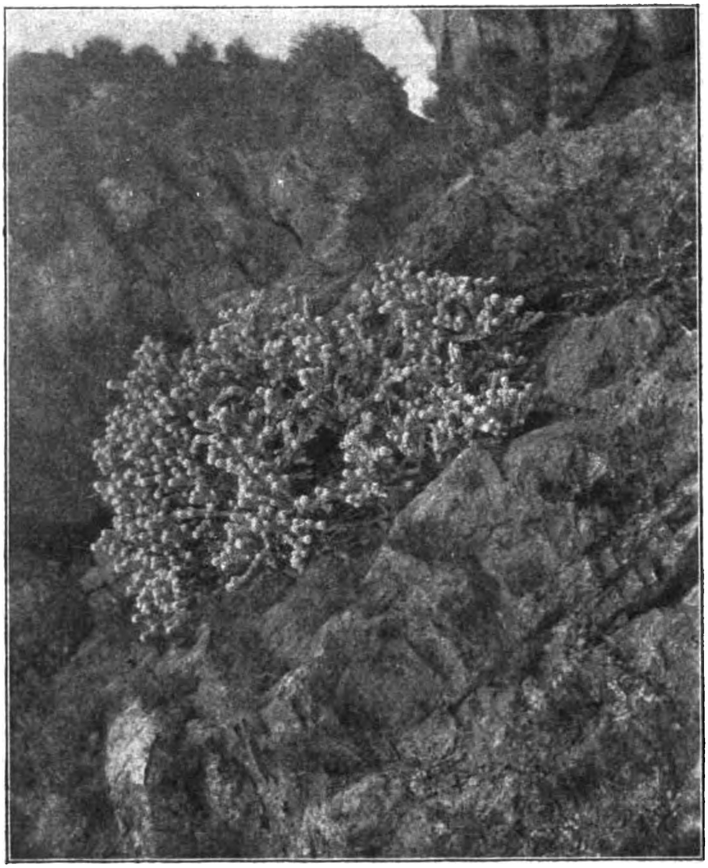

Fig. 53. *Helichrysum coralloides* growing on dry rock, Shingly Range, North-eastern district. Photo L. Cockayne.

drupes &c. to be seen, but by June they have nearly all disappeared, *Gaya Lyallii*, for some time beautiful with autumn colouring, has shed its leaves, dead foliage alone marks the presence of *Ranunculus Lyallii* and *Senecio scorzoneroides*, the shingle-slip species winter beneath the stones and the alpine vegetation, some of it now reddish or purplish in colour, is at rest until the melting of the snow and the increasing warmth of spring.

4. Epharmonic variation and general epharmony.

The high mountains favour epharmonic change more than the other areas dealt with in this book, since not only is there a more diverse variety of edaphic habitats, but considerable differences in altitude, and consequently in climate come into play. As a result, many alpine plants are eminently plastic, a considerable advantage in the struggle for existence and ecesis. The most common change is decrease in stature accompanied by increase in xerophily.

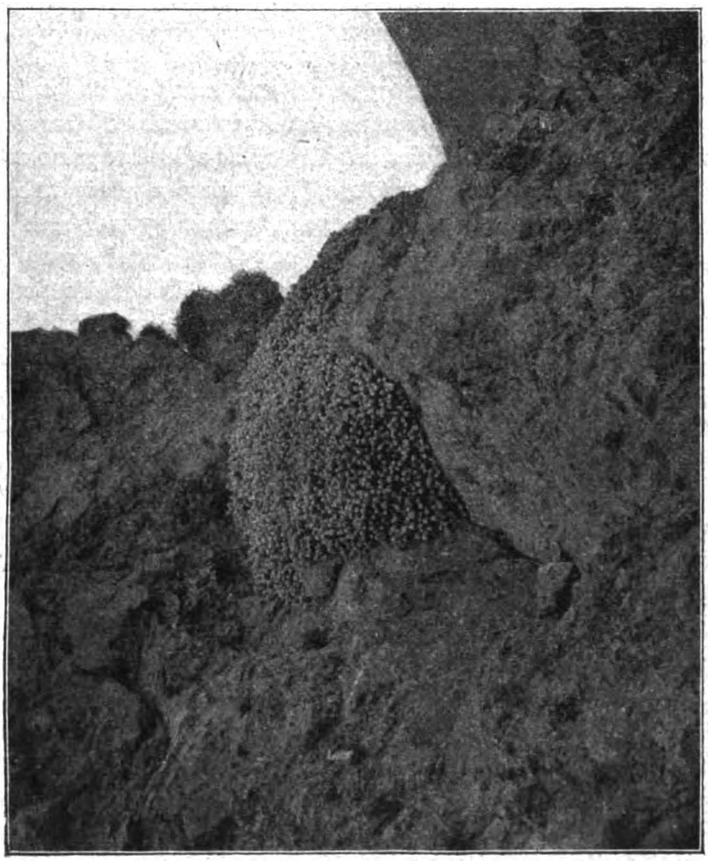

Fig. 54. *Helichrysum coralloides* growing on dry rock but in more exposed position than Fig. 53. and forming a cushion; Shingly Range, North-eastern district at 1500 m altitude. Photo L. Cockayne.

Thus *Leptospermum scoparium*, at times a tree 6 m high in the lowlands with a trunk 40 cm in diam., forms a close leafy mat, or indeed turf, less than 5 cm deep the shoots rooting abundantly. *Podocarpus nivalis* in the lowlands of the Western district is a spreading shrub 1.8 m tall, but on fell-field of the North-eastern district, it closely hugs the ground while its leaves from plants of different stations might well be deemed those of distinct species. Certain plants confined to a definite habitat may appear strongly non-plastic as e. g. the cushion species of *Raoulia*, and yet these, when cultivated in a moist greenhouse, open out their closely imbricating leaves and become very different objects. Every stage of gradation may be seen between the bushy-shrub form of *Aristotelia fruticosa* of a shady forest with its mesophytic leaves, and the strongly divaricating almost leafless plant of the forests' outskirts, its branchlets spinous at their apices. In *Discaria toumatou*, the actual spines can be suppressed altogether by moist-air culture and the shrub become "abnormally" leafy. The case of *Olearia coriacea*, not hitherto published, is of special interest. This is a shrub-composite the leaves of which are small, extremely stiff and coriaceous, the margins strongly recurved and the leaf as a whole so bent as to resemble a saddle, the base being broad and rounded, the centre forming the hollow, while the apical portion, so strongly recurved that the margins almost meet, forms the front of the saddle. Such a leaf appears at first sight a highly specialized xerophytic structure, but bring a plant into a lowland garden, allow it to be overshadowed to some extent by adjacent foliage and the new leaves produced will be perfectly flat. Certain plants may be cushions under one set of conditions and under others, but little dissimilar, branching open shrubs. *Helichrysum coralloides* (Fig. 53), in its "normal form" and station, could hardly be surpassed for general xerophytic form by any other plant with its short straight branches against which the small leaves looking like glossy tubercles are closely pressed, their inner (upper) surfaces and the branch between them being densely woolly; yet when in a less sheltered part of its rock habitat than usual it becomes a distinct cushion (Fig. 54). On the contrary, where some of its shoots are in a still atmosphere the juvenile open leaves, quite different from those of the adult, persist or appear on reversion-shoots. The cupressoid forms of *Veronica* and some of the "normally" leafless species of *Carmichaelia* or *Corallospartium* behave, so far as reversion shoots are concerned, in a similar manner. The above are merely a few examples out of many that could be cited and hardly do justice to the faculty for epharmonic change in the New Zealand alpine plants.

Before concluding, a few words must be said as to epharmony in general amongst the alpine species. As a rule, such is distinctly manifest. For instance, herb-field vegetation is far less xerophytic than that of fell-field, while the species of dry rock and shingle-slip reach the maximum xeromorphy (*Haastia pulvinaris*, *Wahlenbergia cartilaginea*, *Aciphylla Dobsoni*). At the same time, plants very different in their transpiration-activity exist side by side as, e. g., — *Raoulia eximia* with *Celmisia spectabilis* as an epiphyte, the latter the less xerophytic but dependant altogether on the stored-up water of the cushion while the *Raoulia* by means of its deeply-descending root has available the abundant soil-water [1]). Or again in the case of bog-plants, there is no comparison between the xerophily of a dense cushion of *Donatia novaezelandiae* on the one hand and that of the grass-like *Carex Gaudichaudiana* on the other

1) The value of this must however be slight for it is always extremely cold.

or in the subalpine scrub between *Gaya Lyallii* with its thin drip-point leaves and nearly all the other scrub species. The truth seems to be that xerophily in New Zealand generally is out of all proportion to the habitats provided and that, as DIELS (1896: 247 and 296—298) suggested from a study of leaf-anatomy, it is to be referred to an ancient climate rather than to that of the present day. At the same time, it is a fact, as is shown above, that in xerophytic or mesophytic habitats xerophytes or mesophytes rule and that the present conditions are quite sufficient to turn xerophytes into mesophytes and vice versa, but it must not be forgotten that such plasticity is most likely an hereditary character dating from certain ecological conditions in the geological history of New Zealand, or some other land from which the species has come.

Chapter IV. The Plant Formations of the High Mountains.

1. Subalpine Forest.

a. General.

The subalpine forests belong to to two distinct classes, namely those in which species of *Nothofagus* dominate and those where this genus is absent and there is a mixed association of the rain-forest type.

The exact reasons for the presence of either class of forest are not known, but in many cases, the dominance of *Nothofagus* is correlated with comparatively dry conditions which arise either from climate or a specially porous soil. On the other hand, either class of forest may flourish in an extremely wet area as is the case with the mixed subalpine forest of the Western and the *Nothofagus*-forest of the Fiord botanical districts. Possibly, as suggested in Part IV, the present distribution of the two classes of forest depends, in part, upon historical causes.

b. Nothofagus-forest.

1. General.

It is hardly possible to draw a line of demarcation between the *Nothofagus*-association of the high mountains and that of the lowlands adjacent, but the former may be distinguished, in its typical form, by its more open character and specific constitution. *N. cliffortioides* (Plate XXXIX, Figs. 55, 56) is frequently dominant, the other species of the genus being absent over wide areas.

The distribution of the three mountain species of *Nothofagus* depends upon their relative xerophily, *N. cliffortioides*, the most xerophytic, occupying the driest and loftiest stations. *N. Menziesii* with its leaves thicker and smaller than those of *N. fusca*, and its greater epharmonic plasticity, comes midway in its requirements, and so, where the precipitation is excessive, it may form the sole subalpine forest, *N. fusca* dominating at a lower altitude. Where the three species occur in the same locality, *N. fusca*, mixed more or less with

N. Menziesii, may form the lowest belt and *N. cliffortioides*, either pure or mixed with *N. Menziesii*, the highest. The effect of station on the distribution of these species is sometimes striking. Thus, according to F. G. GIBBS, on one part of Mt. Arthur (North-western district), in the subalpine *N. Menziesii* forest, at an altitude of 1020 m, *N. fusca* gives out and *N. cliffortioides* appears, but especially on dry, rocky points. In the extensive *N. cliffortioides* forest near the sources of the River Poulter (Western district, eastern part), *N. fusca* appears occasionally, but it is invariably confined to sheltered gullies, where the conditions are much more mesophytic than on the ridges and slopes.

2. Mountain-beech (N. cliffortioides) forest.

General.

This association rarely descends, even in the South Island, to much below 600 m. The most extensive areas occur on the Volcanic Plateau, Ruapehu and the Kaimanawa Mts. (North Island) and from the North-western to the North Otago botanical districts (South Island). Elsewhere, the association is often wanting, or it occurs merely in patches, or a narrow belt, at the upper limit of the forest. Where there is an abundant rainfall, the association is continuous with montane forest, but where steppe-conditions prevail, it is generally confined to gullies, hollows, or the sheltered side of river-terraces. In such cases, there is no merging of forest and steppe, but the tree-mass ends abruptly.

The relative abundance of species, and the physiognomy of the forest, at any particular point, depends on latitude, climate and soil. In the South Island, according as the precipitation favours forest or steppe, so are there two classes of the association, here termed "wet" and "dry" respectively.

About 39 species belonging to 21 families and 26 genera are fairly common in this association, and these comprise, — 1 forest-tree, 18 low trees and shrubs, 1 woody liane, 2 woody parasites, 7 herbs, 4 grass-like plants and 6 ferns and lycopods. But, there are many plants not included in this estimate, for, at the upper limit of the forest, subalpine-scrub plants enter in, and at the lowest altitudinal limit there is an admixture of lowland species.

The undergrowth is generally not nearly so dense as that of rain-forest, and is made up of but few species. Tree-ferns are wanting, unless *Polystichum vestitum* be so considered, while the smaller ferns are poorly represented both in species and individuals. Woody lianes are of no moment, one or other of the species of *Rubus* being alone present. Epiphytes, certain cryptogams [1]) excepted, are absent. The trees do not raise their roots high above the ground. There is no continuous tier of small trees rising above the shrubby undergrowth.

The following are common members of the association throughout its range: — *Hymenophyllum multifidum*, *Hypolepis millefolium*, *Blechnum penna*

1) Various lichens, especially species of *Sticta*, *Lecanora*, *Ricasolia*, *Parmelia* and *Pannaria* and several mosses, e. g. — *Leptostomum macrocarpum*, *L. gracile*, *Rhacopilum strumiferum*.

marina, *Polystichum vestitum*, *Lycopodium fastigiatum*, *Phyllocladus alpinus*, *Uncinia caespitosa*, *U. uncinata*, *Astelia montana*, *Gastrodia Cunninghamii*, *Elytranthe flavida*, *E. tetrapetala*, *Aristotelia fruticosa*, *Nothopanax simplex*, *N. Colensoi*, *Griselinia littoralis*, *Suttonia divaricata*, *Coprosma parviflora*, *C. cuneata*, *Lagenophora petiolata*.

Dry Mountain-beech forest.

This association occurs on the E. of the volcanoes on the Volcanic Plateau and, in the South Island, on the E. of the main chain of the Southern Alps. It is chiefly distinguished by the poverty of the undergrowth which, frequently, when the substratum is shallow clay on a steep slope, consists merely of young beeches and seedlings with patches of the mosses *Dicranoloma robustum*, *D. leucomoloides* and *D. setosum*. The trees are slender, about 9 m high and their branching is scanty. In many places, the ground is bare, the clay showing through a coating of dead leaves and twigs; where driest the fallen trees are destitute of a mossy covering[1]). Frequently the undergrowth is richer, but large areas may be occupied only by juvenile trees, for *N. cliffortioides* is short-lived, and, as the adult trees fall, light is let in, the seedlings grow vigorously and the forest rapidly regenerates (Plate XXXIX, Fig. 56). *Lycopodium fastigiatum* and the summer-green *Hypolepis millefolium* are frequently abundant.

Where a stream passes through the forest, or in the dampest places, there will be plenty of *Polystichum vestitum*, 60 cm and more high, and sheets of *Hymenophyllum multifidum*[2]). In some localities even *Sphagnum* cushions are present on which may grow *Oxalis magellanica*. The undergrowth, if present, may consist of *Coprosma propinqua*, *C. parviflora*, *C. linariifolia* (Canterbury), and *Pittosporum divaricatum* (Eastern and North-eastern districts). In the Eastern district, *Gaya ribifolia*, *Griselinia littoralis* and various shrubs may grow on the forest's outskirts, but usually the association ends abruptly and one steps from the shade of the beech into the open tussock-land.

The mountain-beech forest to the E. of the volcanoes owes its dry character rather to the permeable pumice-soil than to lack of rain. Besides most of the plants mentioned above, there is abundance of, — *Phyllocladus alpinus*, *Nothopanax simplex*, *N. Colensoi*, *Suttonia divaricata*, *Coprosma microcarpa* and *C. foetidissima*.

Wet Mountain-beech forest.

In this association the undergrowth is denser than in that just described, more species occur, and there is, in places, an actual moss-carpet or small moss-cushions. The forest, too, either makes a continuous covering, extending from the montane to the upper subalpine belt, or, succeeding some other forest-association, forms the uppermost belt of tree-vegetation. All the already-men-

1) Such forest as just described occurs where there is a marked steppe-climate and the description does not fit the association of the Volcanic Plateau.

2) This resists drought through curling up its leaf-segments.

tioned species may be present and, in addition, others according to the geographical position of the forest. Wet mountain-beech forest occurs on the W. and S. of Ruapehu and at many points on the eastern slopes of the Southern Alps, within the limits of the western rainfall.

On Ruapehu, there is a certain amount of *Libocedrus Bidwillii*; tussocks of *Gahnia pauciflora* are common. *Enargea parviflora*, *Libertia pulchella*, *Styphelia fasciculata* and *Myrtus pedunculata* (these two latter prostrate), are abundant, as also *Gleichenia Cunninghamii*, in some places.

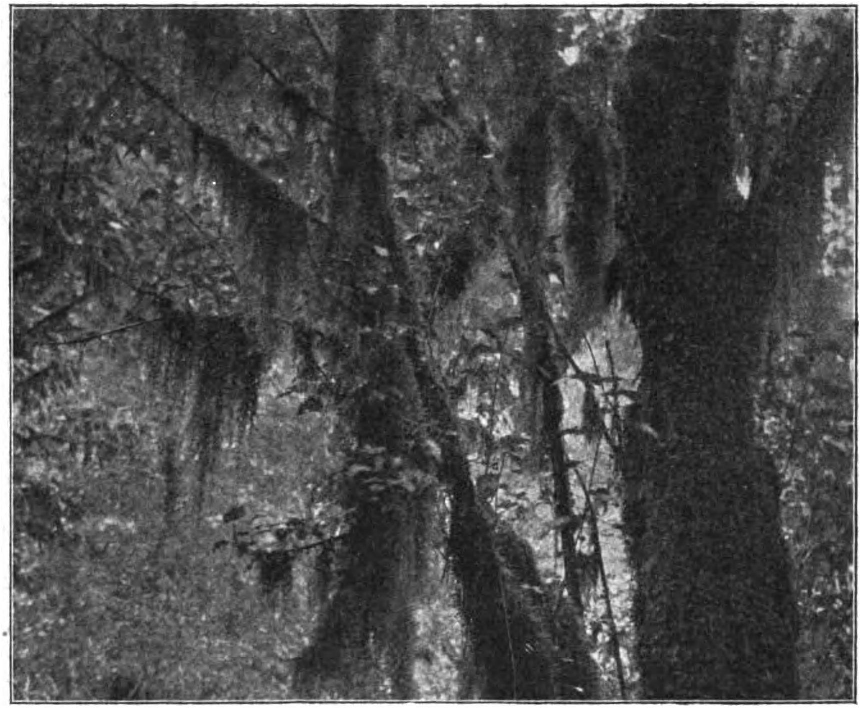

Fig. 57. The epiphytic moss *Weymouthia Billardieri* hanging from twigs of *Gaya Lyallii* — Clinton Valley, Fiord bot. distr. at 600 m alt. Photo L. Cockayne.

The Waimakariri Basin contains an extensive area of this association. Here *Gaya Lyallii* is a striking feature, not only when white with blossom, but from the tender green of its leaves in spring and summer and their beautiful yellow coloration in the autumn.

3. Silver-beech (Nothofagus Menziesii) forest.

General.

This association is common on the North Island dividing range, the Volcanic Plateau, North-western, Fiord and South-Otago districts, but it cannot tolerate a steppe-climate. Besides the dominant *N. Menziesii*, *N. fusca* and *N. cliffortioides* are present in some localities, as also the rain-forest trees, *Libocedrus Bidwillii*, *Podocarpus Hallii* and *Weinmannia racemosa.* The undergrowth may be dense; bryophytes are often conspicuous, and in some forests the number and size of their cushions is remarkable.

Taking the association as a whole, it contains about 63 species of pteridophytes and spermophytes which belong to 24 families and 39 genera and comprise 7 medium-sized trees, 3 small trees, 2 woody lianes, 1 woody parasite, 29 shrubs, 6 herbs, 7 grass-like plants and 8 ferns.

Generally speaking, the dominant silver-beech trees are low, their crowns scanty, their trunks irregular, somewhat buttressed and frequently thickly moss-clad. More light reaches the interior of the forest than in that of mountain-beech, so that the undergrowth is denser. This consists of an upper tier of shrubs and a lower of floor-plants, these, however, not of equal height. In some localities, certain of the shrubs mentioned below rise as small trees above the average level. The following shrubs occur throughout: — *Dacrydium Bidwillii*, *Phyllocladus alpinus*, *Drimys colorata*, *Aristotelia fruticosa*, *Nothopanax Colensoi*, *N. simplex*, *N. anomalum*, *Griselinia littoralis*, *Styphelia acerosa*, *Suttonia divaricata*, *Coprosma foetidissima*, *C. Colensoi*, *C. Banksii*, *C. cuneata* and *C. parviflora*.

The filmy and creeping ferns, *Enargea parviflora* (creeping amongst moss), *Libertia pulchella* and species of *Uncinia* are common floor-plants, but of far greater physiognomic importance are the taller ferns, especially *Polystichum vestitum*, the silvery masses of *Astelia montana* and the tall green tussocks of *Gahnia pauciflora* (North Island and parts of the North-western district, South Island) or *G. procera* (S. Island).

Special details.

α. The Te Aroha forest.

This stands in a class by itself and is excluded from the above general description, since it is a combination of northern montane forest and *N. Menziesii* association [1]). The mountain is 968 m high, but only the final 100 m can be considered subalpine. The forest is low, the floor irregular, the trees more or less gnarled, great clumps of *Gahnia pauciflora* are abundant and bryophytes together with 5—6 species of *Hymenophyllaceae*, including *Trichomanes reniforme*, clothe the trees with a thick mantle.

β. Volcanic Plateau.

Nothofagus Menziesii is taller and with straighter trunks and larger crowns than is general in the association. *N. fusca* is common, especially at the lower limit of the association. At first, *Coprosma tenuifolia* is plentiful but it gives

1) The Northern montane forest is represented by, — *Astelia trinervia*, *Phyllocladus glaucus*, *Ixerba brexioides*, *Alseuosmia macrophylla*, *Quintinia serrata*, *Dracophyllum latifolium* and *Senecio Kirkii*, and the *Nothofagus Menziesii* association by, — *Phyllocladus alpinus*, *Libocedrus Bidwillii*, *Enargea parviflora*, *Libertia pulchella*, two spp. of *Nothofagus*, *Griselinia littoralis*, *Nothopanax Colensoi*, *Coprosma Colensoi* and *C. foetidissima*.

place higher up to *C. foetidissima*. The fern *Polypodium novae-zealandiae* creeps over fallen trees. *Alseuosmia quercifolia* is plentiful.

γ. The Tararua Mountains.

The forest varies much according to its exposure to wind; in the gullies trees are 10 m high, but, on the ridges, they are much smaller. The belt begins at an altitude of about 600 m and ends at 900 m as a minimum. At first, there is plenty of *N. fusca*; *Podocarpus Hallii* and *Weinmannia racemosa* are present throughout, the latter often a shrub. *Pittosporum rigidum* occurs in the uppermost part with other subalpine-scrub plants.

δ. Mount Stokes (Marlborough Sounds).

According to a communication from PHILLIPS TURNER, the belt commences at an altitude of about 750 m, there still being some *Nothofagus fusca*, *Metrosideros lucida* and *Podocarpus Hallii* while common species of the association enter in[1]). At about 900 m, *N. Menziesii* is the sole Southern-beech.

ε. North-western district.

From information supplied by F. G. GIBBS the association on Mt. Arthur has evidently much in common with the last two, but it differs in the presence of *Pseudopanax lineare* and in the colonies of *Dracophyllum Traversii* of its upper portion. At 1020 m, *N. Menziesii* gives place to *N. cliffortioides*.

The subalpine forest of Mt. Rochfort is a combination of *N. Menziesii* and *N. cliffortioides* associations, so far as canopy-trees go, but its contents and habit place it with the former. *Metrosideros lucida*, *Weinmannia racemosa*, *Quintinia acutifolia*, *Pseudopanax lineare* and, near its lower limit, *Metrosideros Parkinsoni*[2]) are common. On the floor are innumerable moss-cushions, of great dimensions, which intermingle, and where a slope descends steeply, form veritable cascades. On the ground, the small shrub *Drimys Traversii* is fairly common. *Astelia montana* is abundant and the tuft-tree *Dracophyllum latifolium*, its trunk more slender than that of *Drimys Traversii*[3]), is frequently conspicuous.

ζ. South Otago and Fiord botanical districts.

The association is common in the above districts. On the Longwood Range it replaces the taxad-forest at the low altitude of 400 m. *Gaya Lyalli* is abundant in the Fiord forest; it appears to be the first arrival when the forest has been destroyed by snow-avalanches, a common occurrence in the narrow

1) Especially *Phyllocladus alpinus*, *Enargea parviflora*, *Suttonia divaricata*, *Nothopanax anomalum*, *N. Colensoi*, the various subalpine species of *Coprosma* and *Pittosporum rigidum*.

2) A low tree of straggling habit with a slender, rigid, leaning trunk covered with warm-brown bark, frequently prostrate and rooting at the base and finally giving off numerous twiggy branches bearing on their flanks the dark-green, rather stiff, ovate leaves, 5 cm in length.

3) There is a slender, wiry, stiff stem creeping just beneath the surface of the ground and then bending upwards as an erect unbranched stem leafy for the greater part, but with leaf-scars below. The leaves are dull olive-green, waxy beneath, thick, coriaceous, oblong-obovate and 2 cm long.

glaciated valleys[1]). Moss-cushions are a striking feature of the Longwood subalpine forest.

c. Mixed Forest.

1. General.

Mixed forest is not so widely distributed in the subalpine-belt as that of *Nothofagus*. In the North Island it occurs on some of the mountains of the Volcanic Plateau and Mt. Egmont, and, in the South Island, in the Western district from the Teremakau Valley to the R. Mahitahi in the S. (ROBERTS 1909: 55), in the North-eastern district on some parts of the Seaward Kaikoura Mts., in the E. part of the Western district near the sources of the Rakaia and some of its tributaries, in the Eastern district on Banks Peninsula and Mt. Peel and, finally, throughout Stewart Island.

Naturally, the associations differ considerably in so wide a range, but, Stewart Island excepted, *Libocedrus Bidwillii* and *Podocarpus Hallii* are frequently the principal canopy-trees. As undergrowth, subalpine-scrub species often play a prominent part. In certain localities the last-named formation is so strongly developed as to become actual forest, in which case the shrub-composites together with *Phyllocladus alpinus*, *Gaya Lyallii* and *Dracophyllum Traversii* are in many situations important members.

2. Kawaka-totara (Libocedrus Bidwillii-Podocarpus Hallii) Association

This, in various forms, is the most important of the subalpine mixed forests. Either the *Libocedrus* or the *Podocarpus* may dominate, and when abundant, the former, with its erect growth and pyramidal head, clearly defines the association.

Forest of Hauhungatahi.

Mount Hauhungatahi is an isolated extinct volcano, 1520 m high, situated on the Volcanic Plateau W. of Ruapehu. It is forest-clad up to about 1140 m altitude. At the base of the mountain, and below, at a height of 780 m or less, the taxad-forest is replaced by a kawaka-totara association. The trees consist of: — *Libocedrus Bidwillii* (first appearing at about 600 m alt.), *Podocarpus Hallii*, *P. ferrugineus*, *Dacrydium cupressinum*, *D. Colensoi*, *Weinmannia racemosa* and *Olea Cunninghamii*. The smaller trees and shrubs of the undergrowth are: — *Phyllocladus alpinus*, *Drimys colorata*, *Carpodetus serratus*, juvenile *Elaeocarpus Hookerianus*, *Aristotelia fruticosa*, *A. racemosa* *Melicytus lanceolatus*, *Myrtus pedunculata*, *Fuchsia excorticata*, *Nothopanax simplex*, *N. Colensoi*, *N. anomalum*, *Pseudopanax crassifolium*[2]), *Schefflera digitata*, *Griselinia littoralis*, *Rapanea salicina*, *Suttonia divaricata*, *Coprosma grandifolia*, *C. robusta*, *C. tenuifolia*, *C. parviflora*, *C. Colensoi*, *C. foetidissima*

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1) For instance in the Clinton valley many stages of regeneration may be observed from almost pure *G. Lyallii* to old gnarled *N. Menziesii* forest.

2) Throughout this book, unless the contrary be stated, this is the var. *unifoliatum*.

and *Alseuosmia quercifolia*. *Dicksonia lanata*, but trunkless, ascends to 1080 m, or more, and may form much of the undergrowth, its fronds being 1.5 m long. Many of the lowland ferns are common and *Leptopteris superba* forms considerable colonies. At an altitude of 960 m (PHILLIPS TURNER 1909:3), *Dacrydium cupressinum*, hitherto abundant, becomes much scarcer and the forest is more typically subalpine with *Libocedrus Bidwillii* dominant and *Podocarpus Hallii*, *Dacrydium Colensoi* and *D. intermedium* abundant. Tussocks of *Gahnia pauciflora* become characteristic and the subalpine-scrub plants of the vicinity enter into the association. In some parts of this association, as where it abuts on the Waimarino Plain, near Horopito and elsewhere, the handsome tuft-tree *Cordyline indivisa* is abundant.

The Mount Egmont forest.

At an elevation of about 850 m the character of the forest changes '*P. Hallii* becoming abundant, and other trees and shrubs not common below appearing in quantity e. g. — *Coprosma tenuifolia*, *Nothopanax Colensoi*. At a somewhat higher altitude, *Libocedrus Bidwillii* appears and soon becomes dominant, though *Podocarpus Hallii*, *Weinmannia racemosa* and *Griselinia littoralis* are abundant[1]). This latter is bent, arched and gnarled, while its trunk may be covered by sheets of the dark, curled leaves of *Hymenophyllum sanguinolentum* and yellowish-green cushions of *Dicranoloma Billardieri*. The common shrubs of the association are: — *Drimys colorata*, *Carpodetus serratus*, *Aristotelia racemosa*, *Melicytus lanceolatus*, *Fuchsia excorticata*, *Nothopanax Sinclairii*, *N. Colensoi*, *Suttonia divaricata*, *Veronica salicifolia* (form with narrow leaves), *Coprosma grandifolia*, *C. tenuifolia* (abundant), *C. parviflora*, *C. cuneata* and *Senecio elaeagnifolius*. An occasional plant of *Rubus australis* is the sole liane. Seedlings and young trees are often epiphytic, especially *Griselinia littoralis* and a narrow-leaved variety of *Coprosma lucida*.

Western botanical district.

On the W. of the Southern Alps, the kawaka-totara belt commences at an altitude of about 600 m, *Podocarpus Hallii* being the first tree to arrive. From the North Island association this differs only in certain floristic details. *Weinmannia racemosa* and *Metrosideros lucida* are abundant at first. Tussocks of *Gahnia procera* are a feature of the floor-vegetation. Lianes and tree-ferns are absent. At the upper limit subalpine shrubs by degrees enter in until a distinct belt of forest results.

On the E. of the Divide an almost identical association as the last occurs in the Rakaia Valley and some of its tributaries. In the lower part of the valley however it differs altogether and is montane rather than subalpine. *Sophora microphylla*, *Fuchsia excorticata*, *Nothopanax parvum*, *Pseudopanax crassifolium*,

1) Forest of this character is not everywhere in the subalpine belt of Egmont. Frequently there is either no *Libocedrus*, or very little indeed, and *Weinmannia racemosa* with far extending irregular branches is dominant. On the western side of the mountain the association is absent and steppe comes to the forest-line.

Coprosma linariifolia and *Carpodetus serratus* are common, while *Libocedrus* is absent. At 900 m altitude, the last named appears and the small trees *Olearia ilicifolia*, *Phyllocladus alpinus*, *Griselinia littoralis*, *Suttonia divaricata* and *Gaya Lyallii* are common. There is a fairly thick undergrowth of subalpine species of *Coprosma*, *Phyllocladus*, *Gaya* and *Veronica salicifolia* and, on the floor, extensive and close colonies of *Polystichum vestitum*.

Eastern botanical district.

The highest peaks of Banks Peninsula doubtless originally carried a belt of kawaka-totara forest, for there are ample remains, while a small piece in its virgin state still exists on Mount Sinclair. *Weinmannia racemosa*, *Metrosideros lucida* and other species are absent, but *Cordyline indivisa*, plentiful in Westland, but not occurring elsewhere E. of the Divide, is fairly common.

3. Southern Rata (Metrosideros lucida) Association.

Forest of this class is wide-spread in the Western district, it is montane rather than subalpine, but as mountain plants descend so low in that locality, it is here included with subalpine-forest.

At above 450 m altitude in the Western district *M. lucida* becomes dominant and the lowland taxads gradually decrease in numbers. *Weinmannia racemosa* is so plentiful in places as to dominate. *Quintinia acutifolia* is conspicuous through its somewhat fastigiate habit as a sapling and the yellowish leaves blotched with purple but pale beneath. Many of the lowland shrubs and ferns are present. The undergrowth is dense, especially in gullies. Bryophytes (species of *Gottschea*, *Schistochila*, *Aneura*, *Mniodendron*, *Plagiochila*, *Lembophyllum* &c.) and *Hymenophyllaceae* abound. *Leptopteris superba* forms extensive colonies.

At the Franz Josef glacier, the terminal face of which descends to 213 m, the southern-rata association comes on to the ice-worn rocks at a few metres from the ice on either side of the glacier. The forest here, the roof of which has the characteristic billowy appearance, consists principally of the following: *Metrosideros lucida* and *Weinmannia racemosa* (the dominant canopy-trees), *Carpodetus serratus*, *Coriaria ruscifolia*, *Aristotelia racemosa*, *Gaya Lyallii*, *Melicytus ramiflorus*, *Pseudopanax crassifolium*, *Schefflera digitata*, *Griselinia littoralis*, *Veronica salicifolia*, *Coprosma lucida*, *Olearia arborescens* and *O. avicenniaefolia*. The pteridophytes include *Hemitelia Smithii* (tree-fern, but here of low stature), several *Hymenophyllaceae*, *Hypolepis tenuifolia*, *Histiopteris incisa*, *Blechnum capense*, *B. lanceolatum*, *Asplenium bulbiferum*, *A. flaccidum*, *Polystichum vestitum*, *Polypodium diversifolium*, *P. Billardieri* and *Lycopodium volubile*.

There is a southern-rata association at 600 m altitude on the exposed ridges on Mt. Peel, an outlyer of the southern Alps abutting on the Canterbury Plain; *Metrosideros lucida* is dominant. It is here about 9 m high and has a short trunk which gives off erect trunk-like branches. Other species present are, — *Leptospermum scoparium*, *Nothopanax simplex*, *Dracophyllum longifolium*, *Coprosma* *rhamnoides* and *Senecio elaeagnifolius*. *Metrosideros lucida* is a rare plant in the E. part of the Western and the Eastern districts and its abundance on Mt. Peel points to a specially wet climate[1]).

4. Stewart Island associations.

The lowness of the Stewart Island mountains and the climatic conditions forbid much change in the forest until the subalpine-scrub or *Leptospermum*-belt be reached (300—600 m altitude). Even *Dacrydium cupressinum* itself and other lowland species ascend into the subalpine-scrub.

Generally at an altitude of 300 m the forest decreases in height, *Metrosideros lucida*, sometimes with prostrate trunks, becomes more abundant, especially on exposed ridges, *Weinmannia* is still plentiful, tall *Leptospermum* may appear, and moss-cushions become more abundant. On the lower hills, so far as is known, at about 270 m, the forest gradually decreases in height until its interior is a tangle of stems from semi-prostrate, slender trunks. On the uneven floor great cushions of *Plagiochila gigantea* and *Dicranoloma robusta* abound (Plate XL, Fig. 58).

5. Low forest allied to subalpine-scrub.

Many of the subalpine shrubs under favourable circumstances become trees, especially the taxads and composites. At various points on the Volcanic Plateau (altitude 1200 m or less), *Phyllocladus alpinus* combined with one or more taxads (*Dacrydium biforme*, *D. Colensoi*, *D. Bidwillii*) forms low almost impenetrable forest 4—6 m high. *Podocarpus Hallii*, *Nothopanax Colensoi* and *N. simplex* are frequent constituents.

In the Western and certain parts of the North-western districts the highest forest-belt consists of *Dracophyllum Traversii* (dominant) together with the following as low trees: — *Dacrydium biforme*, *Phyllocladus alpinus*, *Gaya Lyallii*, *Nothopanax Colensoi*, *Griselinia littoralis*, *Dracophyllum longifolium* and certain shrubby composites[2]). *Libocedrus Bidwillii* and stunted *Podocarpus Hallii* are frequently present. The association is some 4.5 m high. The trunks of the composites are semi-prostrate (Plate XL, Fig. 59), with long strips of papery bark hanging downwards. Above is a tangle of branches; beneath the forest is more or less open. Seen from without, certain of the trees, either through their colour or form, strongly affect the physiognomy of the forest. Thus *Dracophyllum Traversii* is indicated by its candelabra-like crown and huge reddish-brown leaf-rosettes, — *Gaya* by its bright light-green, — *Phyllocladus* by its greyish-green hue, — *Griselinia* by its shining green, darker than that of *Gaya* and the shrub-composites by their rather flat crowns which, in certain species, are whitish in the mass. The undergrowth will consist of divaricating-shrubs of

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1) This is also shown by the presence of the following western plants in the subalpine belt: *Astelia Petriei*, *Coprosma serrulata*, *Leucogenes Leontopodium* (or a near ally).

2) *Olearia arborescens*, *O. macrodonta*, *O. ilicifolia*, *O. mollis*, *O. excorticata*, *O. lacunosa*, *O. avicenniaefolia* and *Senecio elaeagnifolius*.

various genera, species of *Veronica*, *Astelia montana* and colonies of *Polystichum vestitum* and *Blechnum capense*. *Hymenophyllum sanguinolentum* clothes many trunks and branches. A few herb-field species may be present, especially *Ranunculus Lyallii* and *Phormium Cookianum*.

2. Shrub Associations.

a. General.

The mountain shrub-associations fall into the classes open and closed, to the former of which belongs steppe and to the latter heath and scrub. Many of the species are strongly xerophytic but notwithstanding a considerable number thrive also, as has been seen, in the forest under hygrophytic conditions, owing in some cases to great plasticity with regard to their growth-forms.

The number of shrubs, low trees and woody lianes entering into the high-mountain shrub associations is 138 (not endemic only 4) belonging to 25 families and 43 genera. The largest families and genera with the number of species in each are: — *Compositae*, 31; *Scrophulariaceae*, 23; *Epacridaceae* and *Rubiaceae*, 17; *Taxaceae*, 7; *Leguminosae*, 5; *Elaeocarpaceae*, *Myrtaceae* and *Araliaceae*, 4; *Veronica*, 23; *Olearia*, 19; *Coprosma*, 17; *Dracophyllum*, 12 and *Senecio*, 7. From the above it can be seen that nearly 60 p. c. of the species are shrubby-composites, veronicas, epacrids and coprosmas.

Many herbaceous plants, including ferns, occur in various associations, but figures as to these would mislead, since many occupy merely the line of tension between scrub and grass or herb associations. The following however are common in many shrub associations: — *Alsophila Colensoi*, *Polystichum vestitum*, *Danthonia Cunninghamii*, *Gahnia procera*, *Astelia montana*, *Phormium Cookianum*, *Aciphylla conspicua* and *A. maxima*.

b. Open associations.

1. Discaria-steppe.

This occurs on river-or torrent-fans and low river-terrace[1]) in the South Island only; it is wanting in the Western and Fiord botanical districts. Probably, it is a primary association, depending on stability of the substratum, and not a stage of succession following the *Raoulia*-association of river-bed.

At first, the shrubs are dotted about, or in clumps with spaces between, but eventually they grow into one another. The dark colour of the association shows up from afar, especially in contrast to the adjacent yellow tussock-steppe. The general height varies from 1.2—1.5 m, but there are great differences in this regard. Generally, the spinous divaricating *D. toumatou* is the sole shrub, but one or other of the ball-like species of *Veronica* may be present. As in the lowlands, *Clematis marata* may climb over the *Discaria*. The stony spaces

1) In the North Otago district there is a *Discaria* association at from about 180 m upwards both in valleys and on slopes on fertile mica-schist soil. *Olearia odorata* is common. Other species may be: *Muehlenbeckia complexa, Carmichaelia Petriei, C. gracilis* (rare).

between the shrubs may be bare, but usually there is a sparse growth of tussock and some of its accompanying plants where there is forest rather than steppe-climate *Discaria* may develop into a low tree with stout trunk.

2. Dracophyllum recurvum-steppe.

This association occurs only on the Volcanic Plateau and mountains adjacent, and ranges in altitude from about 1080—1350 m. Though distinct enough, it merges into tussock-steppe, scrub and desert, indeed between it and the latter no hard and fast line can be drawn. The dominant plant is *Dracophyllum recurvum* which forms rounded cushions, or low mats, 60 cm in diam., and 10—60 cm deep, made up of much-branching rigid stems bearing semi-rosettes of strongly recurved, reddish-orange, stiff leaves each from 1.2—3.8 cm long. The habitat is strongly xerophytic. The soil, to a great depth, is merely pumice, scoria and andesitic lava mixed with sand from their disintegration. Where level, and sufficient plants are present, there is a layer of sand 2.5—5 cm deep, black in colour through admixture of humus. But the conditions for oxidation are usually too good and but little humus can accumulate, while the dryness of the surface leads to its being blown away. The water-holding capacity of the soil is of the slightest, and the water-table lies far below the surface, moreover the evaporating action of sun and wind comes strongly into play. On a cloudless summer day, when insolation reaches its maximum, the surface-soil becomes burning hot to the naked hand and the heat penetrates markedly for at least 7—8 cm. The plants themselves exercise some influence in supplying shade, making humus, and in the case of *Raoulia australis*, *Racromitrium lanuginosum*, and those prostrate plants with close shoots, which catch the flying sand, provide a seed-bed. Mat-plants, cushion-plants, and those with rotting, persistent, attached vegetative parts, are of moment in conserving moisture. The easily-moved soil brings about conditions similar to those of a dune-area, in fact actual dunes occur. Where there is absence of water and exposure to wind, desert pure and simple results, but with increase of humidity comes a denser plant-covering and the entry of more mesophytic species. In this regard, the winter snowfall acts strongly, so that, in spring and early summer, there is an accumulation of water [1]) on the lower and flatter ground.

About 54 species occur in the association belonging to 21 families and 37 genera. Shrubs number 30 species, herbaceous and semi-woody plants 15, grass-like plants 7, ferns 1 and mosses 1. Regarding the growth-forms &c., 36 are more or less of prostrate [2]) habit, 29 of these being shrubs. Other

1) The effect of excess of water on actual loose scoria, where humus is absent, is shown in those places where a spring bursts forth, for oases arise containing not only actual desert-plants growing with unwonted luxuriance, but bog-plants, e. g. — *Drosera spathulata* which will dot the black cinders with patches of red.

2) In many cases this form is hereditary, but in some it is assumed by "normally" erect shrubs (*Leptospermum scoparium*, *Cassinia Vauvilliersii* etc.) as a direct response to the habitat.

growth-forms represented are: — the cushion, the ball-like, the *Dracophyllum*-form, the divaricating, the leafless and the tussock. Leaf-rosettes, but not always well-defined, occur in 12 species, tomentose leaves in 7 and coriaceous leaves in nearly all.

The landscape varies from a plantless expanse of scoria, by way of a most open covering of a few species, to one almost closed where the whole florula is present. The abundance of *Dracophyllum recurvum* gives a general reddish or reddish-brown colour to wide stretches of the steppe. Where densest, other colours enter in especially: — yellow (*Cassinia Vauvilliersii*) pale-green (*Dacrydium laxifolium*) [see Plate XLI, Fig. 60], (*Gleichenia dicarpa*, *Ourisia Colensoi*), yellowish-green (*Veronica tetragona*) and silver (*Raoulia australis*)[1]). The species are generally more or less flattened to the ground; they grow mixed together forming patches separated by bare ground. Under the most unfavourable conditions, the black scoria is dotted at distant intervals by silvery patches of the *Raoulia*, small straw-coloured tussocks of *Danthonia semiannularis* var. *setifolia*, vivid green semi-cushions of *Pimelea prostrata* and isolated dark rosettes of *Gentiana bellidifolia* (see Plate XLII, Fig. 61), but the scene is one of desolation. More consolidated ground is occupied by abundant reddish-orange patches of *D. recurvum* raised but a few centimetres above the substratum or as higher sand-filled cushions. Open cushions of the leafless flat-stemmed *Carmichaelia Enysii* var. *orbiculata* are not uncommon. *Gaultheria rupestris* and *Anisotome aromatica*[2]) are abundant.

Where conditions are more favourable, the shrubs etc. growing mixed catch the flying sand and build irregular mounds 30 cm high with the margins either ragged or held firmly by a close mat of *D. laxifolium* or *Podocarpus nivalis* which may extend out to the bare ground. Dunes are occupied by the same species as the mounds, but in addition there may be: — *Coriaria thymifolia*, *Muehlenbeckia axillaris*, *Olearia nummularifolia*, *Phyllocladus alpinus* and stunted *Nothofagus cliffortioides*.

c. Closed Associations.

1. Veronica scrub.

A close-growing mass of shrubs made up altogether, or principally, of one or more species of *Veronica* is a common feature of the upper montane and subalpine belts. Its presence, generally denotes a steppe-climate, but it demands more shelter from wind than does tussock-steppe, its principal development being in the river-valleys eastward of the South Island Divide. A favourite situation is the sheltered side of river-terrace. It occurs also on the

1) Reddish tussocks of *Danthonia Raoulii* dotted about, or in clumps, add to the variety. In summer the abundant blossoms of *Celmisia spectabilis*, *Ourisia Colensoi* and *Gentiana bellidifolia* — all white, change the aspect of the scene.

2) In small, dense, rounded patches, the leaves in rosettes pressed closely to the ground and the root stout and very long. Most likely an unnamed variety.

outskirts of the lower subalpine forest; on torrent-fans just where they issue from a gorge, or in the mouth of the latter; on ancient river-bed and on coarse débris at the foot of some disintegrating cliff. The soil that the association affects ranges from stones mixed with fine clay and sand to deep clayey loam. The wind-factor may be extremely powerful on river-bed, but much modified on river-terrace. The soil-water must vary considerably, but even on a steep terrace-face may be fairly abundant. Winter snow is usually a factor of little moment.

The species number about 50 which belong to 16 families and 23 genera. Low trees number 2 species, shrubs 34, lianes 10 and ferns 4.

The shrubs are erect. Their principal growth-forms are the ball-like and the divaricating. Of less importance are the *Dracophyllum* and shrub-composite forms. The lianes are slender; most not only climb, but form bushes approximating to the divaricating-form. Leaving the ferns out of consideration, 2 of the species are mesophytic and several, at most, subxerophytic. Eight have tomentose leaves.

The association varies from a close, bright-green growth of species of *Veronica* to a dense, dark-coloured scrub about 1.8 m high, of divaricating shrubs[1]) bound together by the various lianes[2]) and relieved in places by the green of *Veronica*[3]) or the whitish hue of *Olearia avicenniaefolia*; *Discaria toumatou* is frequently present. Beneath the shrubs the ground may be bare or occupied more or less closely by some of the ferns[4]). On many river-beds, if the rain-fall is high, or near streams flowing through steppe or fell-field or where water oozes out of the ground are thickets of the glossy-leaved *V. buxifolia* var. *odora* round as a cricket-ball. The cupressoid *V. salicornioides* sometimes grows in the North-eastern district in soil saturated with ice-cold water. Coarse rocky débris in the North-eastern and Eastern districts, larger in size than that of "Shingle-slip", is occupied in the first instance by *Veronica*-scrub and not tussock-steppe. *Rubus cissoides* var. *pauperatus* or *R. subpauperatus* and the rigid, open, dark-coloured almost leafless cushions of *Hymenanthera dentata* var. *alpina* are often present.

2. Subalpine-scrub.

General.

The term "Subalpine-Scrub" is here applied to that assemblage of stunted trees, — trees no longer, and shrubs of various growth-forms, which, on many

1) *Aristotelia fruticosa*, *Pittosporum divaricatum*, *Coprosma rugosa*, *C. parviflora*, *C. propinqua* and *Corokia Cotoneaster*, *Olearia virgata*, *O. odorata*.

2) *Rubus australis*, *R. schmidelioides* var. *coloratus*, *R. subpauperatus*, *Parsonsia capsularis*, *Muehlenbeckia complexa*, *M. australis* and *Helichrysum dimorphum* (Eastern district, limited to a small part of the R. Waimakariri basin).

3) The species differ in the botanical districts as follows: — Volcanic Plateau, *V. laevis*; North-eastern and Sounds portion of Ruahine-Cook, *V. Menziesii*; North-eastern and Eastern, *V. Traversii*, *V. leiophylla* and *V. glaucophylla*; North-western, Western and Fiord, *V. subalpina*, *V. Cockayniana*.

4) *Polystichum vestitum*, *Cystopteris fragilis*, *Hypolepis millefolium*, *Blechnum penna marina*.

high mountains, form either a belt above the forest-line or make thickets, large or small, on river-beds, in gullies, in hollows and even on mountain-slopes.

The general ecological conditions that determine the presence of the formation are, — altitude, (which decreases from N. to S. or according to edaphic xerophily); violent wind, (but less than herb and grass formations can tolerate); a heavy winter snow-fall, (but not the maximum), and frequent rain at all seasons. This last factor leads to the presence of a xerophytic soil rich in peat or raw humus. But, in the dry mountain areas, scrubs likewise occur, some of which are strongly bound up with edaphic conditions, as in the case of the serpentine Mineral Belt and the *Senecio Monroi* scrubs of the North-eastern botanical district.

The species number about 108 which belong to 26 families and 45 genera. Sixty eight species are common to subalpine-scrub of both the North and South Islands, 7 species are peculiar to the former and 31 to the latter island. Stewart Island contains 42 of the species in the above total estimate, but 10 do not occur in the formation while a number of the remaining play a very minor part[1]). By far the greater part of the really important members of the subalpine-scrub, as a whole, consists of *Taxaceae*, *Epacridaceae*, *Rubiaceae* and shrubby *Compositae*. *Nothofagus cliffortioides*, *N. Menziesii*, *Gaya Lyallii* and *Suttonia divaricata* are also important members in many localities.

Coming now to the growth-forms, there are 90 shrubs or stunted trees, 1 liane, 5 herbs or subshrubs, 4 grass-like plants and 8 ferns. Regarding the shrubs &c. the most important growth-forms are: — the shrub-composite 24; the *Dracophyllum* 6; the divaricating 13 and the more or less cushion-like 5. Many of the remainder are of much closer growth, than normal, with their branches gnarled and crowded together. With regard to leaves, 46 species have them small and coriaceous, 26 medium and coriaceous, 6 rather long and needle-like, 5 cypress-like, 3 large and coriaceous, 4 have thin leaves and 23 have dense tomentum on the undersurface.

The subalpine-scrub associations differ from one another in density, floristic composition and physiognomy in different localities, and dissimilar scrubs may occupy contiguous areas. According as shrub-composite, cupressoid-taxad, *Gaya Lyallii*, *Phyllocladus alpinus*, stunted *Nothofagus*, *Dracophyllum* or divaricating-shrub dominate, so is there a different and distinct facies. In many parts of the Southern Alps *Phyllocladus* and *Gaya* lend a most distinct appearance to adjacent patches of scrub.

A typical subalpine scrub of a wet climate consists of a number of rigid or wiry-stemmed shrubs which grow into one another while the main branches of many are parallel to the slope and project downwards. The height may be from 2—3 m and the roof fairly even. The density may be so great that one cannot force a passage through, but must actually walk upon the top!

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1) In addition *Olearia divaricata* and *Dracophyllum politum* members of subalpine-scrub in Stewart Island only.

Where there is an actual belt above the forest, it gradually decreases in height as one proceeds upwards and eventually ends in low bushes hugging the ground, herb-field or fell-field cutting gaps into the association. Scrub is taller in gullies than elsewhere and on their shaded side attains its maximum height. The following are the principal classes of subalpine scrub based on the dominance of distinctive growth-forms. Though distinct enough in typical examples, intermediates referable to more than one class are common.

α) Shrub-composite scrub.

One or more of the tree-like species of *Olearia* or *Senecio* is dominant. Various divaricating-shrubs (spp. of *Coprosma*, *Aristotelia fruticosa*, *Pittosporum divaricatum*, *Suttonia divaricata*) will be present. Also one or other of the fastigiate species of *Dracophyllum*, *Phormium Cookianum*, *Cassinia Vauvilliersii*, *Phyllocladus alpinus*, *Nothopanax Colensoi* and one or two species of *Veronica* are frequent members and *Dracophyllum*, *Phyllocladus*, *Cassinia or* even *Veronica* may in places dominate.

The trunks of the tree-composites are prostrate and yet tree-like, their horizontal spread exceeding the height of the association. The divaricating-shrubs greatly increase the general density. The roof will be fairly level but pierced here and there by *Dracophyllum* (Plate XLV, Fig. 64). Shrub-composite scrub requires a high rainfall for its full development. In the North Island, it occurs on Mt. Hikurangi, the Ruahine and Tararua Mts. and Mt. Egmont. In the South Island, it is a characteristic feature of the Western botanical district on both sides of the Divide, making, in many places, a broad belt above the forest and partly filling the cirques at the sources of glacial rivers. According to HECTOR (1869: 4) and BUCHANAN (1869: 30[1]) similar scrub occurs on the western side of the Fiord district; it is also highly developed in Stewart Island. In what follows an attempt is made to give some idea of the chief floristic characteristics of shrub-composite scrub in different localities.

Mt. Hikurangi (*East Cape district.*) *Senecio elaeagnifolius* and *S. Bidwillii* are dominant. Other species are: — *O. nummularifolia*, *O. Colensoi* together with *Phyllocladus alpinus*, *Podocarpus nivalis*, *Dacrydium Bidwillii*, *Aristotelia fruticosa*, *Nothopanax Colensoi*, *Dracophyllum montanum*, *Veronica laevis*, *V. tetragona* (J. ADAMS, 1898: 418 et seq.).

Mt. Egmont (*Egmont-Wanganui district*). The scrub commences at about 1140 m and ceases at about 1240 m. *Senecio elaeagnifolius* var. *Buchanani* is generally dominant, but sometimes *Dracophyllum filifolium* rules. The other principal species are: — *Podocarpus Hallii*, *Carmichaelia australis* (var. with narrow stems), *Nothopanax Colensoi*, *N. Sinclairii*, *Griselinia littoralis*, *Suttonia divaricata*, *Veronica salicifolia* var., *Coprosma tenuifolia*, *C. cuneata* (erect, not of divaricating form), *C. parviflora*, *Olearia arborescens* and *Cassinia Vauvilliersii*.

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1) "At 2500 feet altitude, the trees cease, and a belt of stunted gnarled shrubs are passed through, to the bald mountain top, this belt is sometimes found to consist of *Olearia Colensoi* only, and is very difficult to pass through, from the branches interlacing."

Tararua Mts. (*Ruahine-Cook district*). *Olearia Colensoi* is frequently dominant, but *O. arborescens* and *Senecio elaeagnifolius* are often abundant. Other shrubby species are: — *Pittosporum rigidum*, *Nothopanax Colensoi*, *N. Sinclairii*, *N. anomalum*, *Dracophyllum longifolium*, *D. filifolium*, *Suttonia divaricata*, *Veronica salicifolia* var., *Coprosma cuneata*, *C. foetidissima*, *Olearia excorticata*, *O. lacunosa* and *Senecio Bidwillii*.

Ruahine Mountains (*Ruahine-Cook district*). According to information supplied by B. C. ASTON all the Tararua species occur except *O. excorticata* and *O. lacunosa* while *Coprosma tenuifolia*, *C. microcarpa*, and a species of *Hoheria* are present. In some places are extensive colonies of *Cordyline indivisa*.

Southern Alps. *Olearia ilicifolia* or *O. Colensoi* are frequently dominant; *O. arborescens*, *O. macrodonta*, *O. nummularifolia*, *O. avicenniaefolia*, *Senecio Bidwillii*, var. *viridis* and *S. elaeagnifolius* are common shrub-composites [1]). The following occur throughout and are often important constituents: — *Phyllocladus alpinus*, *Dacrydium biforme*, *D. Bidwillii*, *Podocarpus Hallii*, *P. nivalis*, *Phormium Cookianum*, *Pittosporum divaricatum*, *Carmichaelia grandiflora*, *Aristotelia fruticosa*, *Gaya Lyallii*, *Nothopanax Colensoi*, *N. simplex*, *Pseudopanax lineare*, *Griselinia littoralis*, *Gaultheria rupestris*, *Dracophyllum longifolium*, *D. Lessonianum* [2]), *Archeria Traversii*, *Veronica salicifolia*, *V. subalpina*, *Coprosma serrulata*, *C. cuneata*, *C. parviflora*, *C. ciliata*, *C. foetidissima* and *C. ramulosa*. *Olearia moschata* is common from about the latitude of Mt. Cook southwards [3]).

Stewart Island. At first the forest-trees, much dwarfed, occur abundantly, but early on *Olearia Colensoi* becomes dominant. *Leptospermum scoparium* and *Dacrydium Bidwillii* are, in places, plentiful, tussocks of *Gahnia procera* are frequent. Other important species are: — *Nothopanax Colensoi*, *N. simplex*, *Griselinia littoralis*, *Dracophyllum Menziesii*, *D. longifolium*, *D. Pearsoni*, *D. politum*, *Suttonia divaricata*, species of *Coprosma* as for Southern Alps and *Senecio elaeagnifolius* (Table Hill).

North-eastern district. Shrub-composite scrub of a different character made up of one species only (*Senecio Monroi*) occurs on the Inland Kaikoura Mts. and adjacent parts of the district. The substratum is coarse shingle-slip. Elsewhere the species is a rock-plant, and in this case the stony ground, as it slowly grows, is peopled by plants from the mother rock.

β) Cassinia scrub.

A heath of *Cassinia* occurs in many parts of the montane South Island where there is a steppe-climate but in parts of the North-eastern district, Flagstaff Hill near Dunedin (South Otago district) and indeed in many more

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1) *O. excorticata* and *O. lacunosa* are abundant in N. Westland and some parts of Nelson.

2) *Dracophyllum Traversii* is abundant in the North-western and Western districts and *D. Menziesii* in the Fiord district. *Senecio cassinioides* is abundant in the Hooker valley.

3) It is frequently dominant where scrub is in patches. Scrub of this character is common on the Takitimu Mts., Southland.

localities there is a closed scrub with *C. Vauvilliersii* or *C. albida* (North-eastern district) dominant. With these may be associated one or more shrub-composites, *Phormium Cookianum* and on Flagstaff Hill the tree-fern *Alsophila Colensoi.*

γ) Phyllocladus scrub.

Phyllocladus alpinus is dominant. The scrub has frequently the same composition almost as the adjacent shrub-composite association, but the dominance of the taxad lends a distinct facies and colour. The low *Phyllocladus* forest of the Volcanic Plateau already described when of low stature is a scrub, as in certain gullies on Mt. Tongariro and the Kaimanawa Mountains. Its other species are: — *Dracophyllum montanum* (dominant in places), *Nothopanax Colensoi*, *N. simplex*, *N. Sinclairii*, *Griselinia littoralis*, *Leptospermum scoparium*, *Coprosma cuneata*, *C. parviflora*, *C. foetidissima* and *Olearia nummularifolia.* In the S. Island *Phyllocladus* scrub is common in the eastern part of the Western district.

δ) Mountain-ribbonwood (*Gaya Lyallii*) scrub.

This occurs throughout the chain of the Southern Alps except in the North-east, and in the North-west districts. It is dependant on a high rainfall. The association readily grades into forest, and such in the Fiord district appears to be an early stage of *Nothofagus Menziesii* forest. The vivid light green of the *Gaya* clearly marks the association even from a distance. The accompanying plants are those of the neighbouring scrub, already sufficiently defined.

ε) Cupressoid-taxad scrub.

On boggy ground occupying roches moutonées, truncated spurs and ancient moraine on the central chain of the Southern Alps are open or dense scrubs with *Dacrydium biforme* and *D. Bidwillii* dominant. *D. Bidwillii* alone forms patches of scrub on quite dry moraine [1]) fully exposed to wind and sun throughout the South Island where there is a steppe-climate. The shrub is then generally prostrate and forms low circular loose cushions, its branches creeping and rooting. The erect form is also, at times, dominant in ordinary mixed subalpine scrub.

Mount Greenland (915 m), an isolated mountain in the N. of the Western district, contains near its summit a very distinct form of taxad-scrub (Plate XLIV, Fig. 65), which though extremely dense is erect, but on the flat mountain-summit becomes low and open. The following is its composition: — *Dacrydium biforme* (dominant), *Phyllocladus alpinus*, tussocks of *Gahnia procera*, *Pittosporum divaricatum*, *Quintinia acutifolia*, *Weinmannia racemosa*, *Elaeocarpus Hookerianus*, *Nothopanax Colensoi* var. *montanum*, *Pseudopanax lineare*, *Leptospermum scoparium*, *Metrosideros lucida*, *Dracophyllum Traversii*, *D. longifolium*, *Olearia lacunosa*, *O. avicenniaefolia*, *Coprosma cuneata*, *O. Colensoi* and

1) The well-known "Wilderness" on the main road from Lumsden to Lake Te Anau is a good example of this association.

Senecio elaeagnifolius. The main feature of this association besides its erect habit is the mixture of forest and scrub species.

In the North-western district *Dacrydium intermedium* is an important member of taxad-scrub at 600 m altitude and upwards. Flat, boggy ground, on certain Stewart Island hills, is covered with *D. intermedium* scrub, on the floor of which is prostrate *D. Bidwillii.*

η) Dracophyllum scrub.

Dracophyllum longifolium, or allied species, may occur in such quantity in what would be otherwise *Olearia*-scrub as to give it a different facies. On dry mountains of the South Island *D. uniflorum* forms on stony ground a more or

Fig. 66. Scrub of *Leptospermum scoparium* on Frazer Peaks, S. of Stewart Island; on right where extremely close it has been reproduced after burning. Photo L. Cockayne.

less pure rather open scrub of a brownish colour. It burns readily and so is less in evidence than it was in the primitive vegetation. *Veronica Traversii*, species of *Cassinia*, *Olearia cymbifolia*, *Podocarpus nivalis* and *Helichrysum microphyllum* (North-eastern district) may be associated plants.

ϑ) Manuka (Leptospermum) scrub.

This is chiefly a community of the lower subalpine or montane belts and differs but little from the allied lowland association. In Stewart Island, however, thanks to its tolerance of excessive wind through its epharmonic plasticity, it forms a belt at about 450 m altitude, or even lower (Fig. 66). At first it is mixed with certain forest shrubs, but it eventually becomes pure, much reduced in size and with bare stems and small head of twisted branches. Beneath are moss-cushions, carpets of *Lycopodium ramulosum*, tussocks of *Gahnia procera*, low-growing *Styphelia acerosa* and prostrate *Dacrydium Bidwillii*.

There is closely-related *Leptospermum* scrub on certain mountains in the Western district (e. g. Mt. Greenland.)

η. Southern-beech (Nothofagus) scrub.

The two subalpine species of *Nothofagus* respond more readily to scrub-conditions than do the trees of other forest-associations and, in consequence more than hold their own in competition with subalpine shrubs proper, so that both *N. Menziesii* and *N. cliffortioides* forests are frequently succeeded throughout New Zealand by a scrub in which one or other dominates. Such an association may consist almost altogether of *Nothofagus cliffortioides*, as on many of the drier mountains of the North-eastern district. Generally where there is an abundant precipitation many of the ordinary subalpine-scrub species accompany the southern-beeches[1]).

3. Rock Associations.

a. General.

Rock at various stages of plant-colonization is a common feature of the high mountains, but different ranges vary greatly in this regard. Speaking generally, the alpine belt and the river gorges of the lower levels are the most rocky localities. The volcanoes of the North Island furnish much rock with their extensive lava flows (see Plate XLVI, Fig. 67), weathered into fantastic forms, or, as huge blocks, piled one upon another. Mountain rock may form perpendicular cliffs, as in river gorges, much weathered crags, or be worn down to the level of the hillside. In any case, perfectly smooth rocks are rare and there are generally abundant crevices, ledges and hollows where soil can accumulate. The conditions offered for plant-life are most diverse according to the position of the rock with regard to sun, wind and moisture, and they range from intensely xerophytic to distinctly hygrophytic. Even opposite sides of the same gully often contain these opposing classes.

The species of the various rock associations fall into the three categories of, — those confined to rock; those almost confined thereto and those which belong equally to other formations. These latter may be divided into facultative chasmophytes and soil-demanding plants. Such a soil is readily formed

1) On the S. of Ruapehu the scrub commences at about 1200 m; *N. cliffortioides* is dominant. *Phyllocladus alpinus*, *Dacrydium biforme*, *D. Bidwillii*, *Nothopanax Colensoi*, *N. simplex*, *Myrtus pedunculata*, *Coprosma foetidissima*, *C. cuneata* and tussocks of *Gahnia pauciflora* are common. On Mt. Rochfort (North-western district) the scrub begins at about 890 m and consists of *N. cliffortioides* (dominant), *N. Menziesii* (both beeches about 2.5 m high) together with abundance of *Dacrydium biforme* and *Leptospermum scoparium*. Other constituents are: — *Phyllocladus alpinus*, *Pittosporum divaricatum*, *Pseudopanax lineare*, *Dracophyllum montanum*, *Suttonia divaricata*, *Olearia Colensoi* and *Senecio elaeagnifolius*. — The scrub of the Longwood Range (South Otago district) contains a good deal of *N. Menziesii* but there is much *Dacrydium Bidwillii*, so it may be considered an intermediate type.

in a moist climate both on flat rocks and in depressions and hollows, so that a plant-covering may eventually be established not to be distinguished from that of the adjacent herb-field. At the same time, there are some species that especially affect soil-covered rocks and are almost confined thereto[1]). The number of species fairly common on rocks is 161 belonging to 36 families and 72 genera. This estimate is not of much moment, since many wet-mountain plants are here excluded which, in one place or another, grow on rocks. Far more important is it, that 45 species appear to be confined to rock of which 36 are purely mountain-plants. They may be classified as follows: — Shrubs 17; semi-woody 8; herbs 16; grass-like 2 and ferns 2. Cushion-plants number at least 12 (26 p. c.) and some of the other growth-forms are at times changed to cushions; rosette-plants number 11, some most closely pressed to the rock, and cupressoid shrubs 5. The leaves of 16 are tomentose or distinctly hairy. Five species of *Raoulia* of cushion-form, 3 of *Helichrysum* of cupressoid-form, their leaves woolly and the rigid, excessively thick-leaved *Aciphylla Dobsoni* are intensely xerophytic, but the remainder, though generally xerophytic enough, are not more so than many other alpine plants, and it is hard to guess why they should be confined to rock, in many cases always dry, especially as most can be cultivated readily in ordinary garden soil.

b. The Rock-associations.

1. The North Island Volcanoes.

Here there are no special rock-plants. The vegetation is scanty and, besides mosses and lichens consists only of deep-rooting desert or steppe xerophytes, especially — *Danthonia semiannularis* var. *setifolia*, *Poa Colensoi*, *Anisotome aromatica*, *Gaultheria rupestris* and *Helichrysum bellidioides*[2]).

2. The Tararua Mountains.

Although subject to much rain, mist, and cloudy skies, these mountains possess two extreme xerophytes, — *Raoulia rubra* and *Helichrysum Loganii*, the former a typical vegetable-sheep, its cushions *green* however and about 30 cm in diam., and the latter a small cushion-plant clothed with whitish wool, its branches slender and leaves small and imbricating. The remaining rock-vegetation is made up of fell-field plants especially, — *Anisotome aromatica*, *A. dissecta*, *Pentachondra pumila*, yellowish-green cushions of *Phyllachne Colensoi*, *Helichrysum bellidioides* and *Leucogenes Leontopodium*. Where rocks are near the subalpine scrub, they are occupied by some of the shrubs, notably *Senecio Bidwillii*.

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1) *Anisotome pilifera*, *Dracophyllum Kirkii* and *Celmisia Walkeri*.

2) On Ruapehu, Tongariro &c. *Veronica spathulata* will be present. The subalpine-scrub shrubs of the vicinity are slowly colonizing the great lava-flow from Mount Te Mari. On Egmont, most of the fell-field and steppe plants occur on rock, but *Coprosma repens*, *Pentachondra pumila*, *Drapetes Dieffenbachii*, *Forstera Bidwillii* and *Celmisia glandulosa* var. *latifolia* are common in addition to the above.

3. Dry Mountains (South Island).

Commencing with one of the most xerophytic stations, much-weathered greywacke, standing out from alpine shingle-slips in the North-eastern district (1200 m and upwards), the dominant plant is a black fruticose lichen. Pressed as closely to the rock as possible will be numerous, hard, circular greyish cushions of *Raoulia bryoides*, the largest some 30 cm in diam. and 17 cm deep. Here too will be the remarkable *Helichrysum coralloides*, an open shrub some 40 cm high, if sheltered [1]), but a true cushion, if fully exposed; its shoots cylindrical, 8 mm in diam. and the small, glossy appressed leaves looking like tubercles, the spaces between being packed with white wool [2]). *H. Selago* agg. and *H. microphyllum* are also plants of this association, but the three are rarely present at the same time. Other plants are: — *Hymenanthera dentata* var. *alpina*, its rigid, semi-spinous, leafless, stout stems forming open divaricating cushions; *Veronica decumbens* or *V. pinguifolia* pressed close to the crevice; *Pimelea Traversii*, small loose cushions of *Colobanthus acicularis*, the fine white-flowered *Myosotis saxatilis*, the rosettes of *Epilobium crassum* and possibly broad flattened sheets of *Podocarpus nivalis*. *H. coralloides* is confined to the North-eastern district, but dry alpine rocks in many parts of the Eastern and North Otago districts bear a closely allied association [3]).

Equally xerophytic is the Vegetable-sheep (*Raoulia eximia*) association of low rock, even with the surface or slighly raised above the desert of shingle-slip, at an altitude of from 1200—1800 m and upwards. The great cushions, already described, frequently grow into one another, forming hard, white, amorphous masses 2 m in length, or more. Thanks to the wet raw humus within, colonies of *Celmisia spectabilis*, *C. viscosa*, *Aciphylla Colensoi* and *Danthonia flavescens* grow as epiphytes on the cushions, being quite independent of the rock. The station, fully exposed to sun and wind and subject to great daily extremes of temperature at all seasons, except when buried beneath the snow in winter, is one of extreme xerophily.

The *Olearia insignis* association, already described for the coast and the lowlands, ascends to about an altitude of 900 m, clothing the cliffs of river valleys of the North-eastern district. As a higher altitude the *Olearia* gives out but *Senecio Monroi* ascends to 1500 m, or more.

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1) On shady rocks in river gorges of the Inland Kaikoura Mts. the shrub may be as much as 90 cm high and the width equalling the height and the branches spreading and drooping.

2) The leaves are densely tomentose beneath and it is the hairs of adjacent leaves being entangled which makes the "white" wool. The actual stem is very slender and quite glabrous.

3) *Veronica pinguifolia*, *V. epacridea*, *V. tetrasticha*, *Gaultheria rupestris* and stunted *Leucogenes grandiceps* are common in the Eastern district. *Veronica Buchanani*, and near the mountain summits *Pachycladon novae-zelandiae* occur in North Otago. *Radicula latesiliqua*, *R. fastigiata* and *R. Enysii* with large rosettes clinging to the rock and far-penetrating thick root are local species occurring respectively in the North-western, the North-eastern and Eastern districts respectively, but *R. fastigiata* also extends into the Western district in the Mount Cook area.

Speaking of the lower subalpine rocks, so far as the dry mountanis as a whole are concerned, they are populated to no small degree by certain plants from the adjoining steppe &c., and the following are found in most parts: — *Dichelachne crinita*, *Danthonia semiannularis*, *Poa caespitosa*, *Poa Colensoi*, *Festuca novae-zelandiae*, *Agropyron scabrum*, *Phormium Cookianum*, *Nothofagus cliffortioides*, *Exocarpus Bidwillii*, *Muehlenbeckia axillaris*, *Stellaria gracilenta*, *Scleranthus biflorus*, *Crassula Sieberiana*, one or other of the tall, leafless species of *Carmichaelia*, *Coriaria ruscifolia*, *Discaria toumatou*, the *Hymenanthera* as before, *Leptospermum scoparium*, *Aciphylla Colensoi*, *A. squarrosa* agg., *Angelica montana*, *Styphelia acerosa*, *S. Fraseri*, *Suttonia nummularia*, *Wahlenbergia albomarginata*, *Helichrysum bellidioides* and *Crepis novae-zelandiae*. True rock-plants of such stations are: — *Asplenium Richardi* (where shaded), *Colobanthus acicularis*, *Epilobium gracilipes* (Trelissick Basin on limestone, Eastern district), *E. brevipes* (North-eastern district), *Myosotis Goyeni* (North Otago to North-eastern district), *Veronica Raoulii* (North-eastern to North Otago district), *Celmisia Monroi* (North-eastern district), *C. bellidioides* and *Helichrysum Sinclairii* (North-eastern district), *C. densiflora* and *Veronica pimeleoides* (North Otago district), *Anisotome brevistyle* (N. and S. Otago districts).

4. Wet mountains of the Southern Alps and Stewart Island.

The number of true rock-plants for this area is only 12, of which 6 extend to the dry mountains. Two however are vegetable-sheep of the same type as those of the dry mountains but neither approach the great cushions of *Raoulia eximia* in size though *R. Goyeni* is quite common on the highest rocks of Stewart Island.

In the lower subalpine belt the rocks are altogether in the forest-areas, and when in the open occur only on river-beds or the sides of gorges. In such places, various forest-trees and subalpine shrubs are common jutting out from the rocks. In the wettest districts extremely steep cliffs may be actually covered with a close scrub, the rock having become faced with a thick sheet of soil held in position by a network of matted roots. At times, the whole of such a covering slips away for many metres leaving the steep rock-face bare and dripping. Rock of such gorges in the Western district at an early stage may be merely dotted here and there with various herbs, e. g. — *Angelica montana*, *Veronica linifolia*, *Epilobium glabellum*, *Geum parviflorum*, *Calamagrostis pilosa* and *Senecio Lyallii*. Extensive colonies of *Phormium Cookianum* are a characteristic feature.

In the upper Clinton Valley (Fiord district), on the smooth face of the precipice where water constantly trickles, there is a curious association consisting of a close growth of a species of *Hepaticae* which is hidden by a prostrate grass, its culms pressed closely to the liverwort, pointing downwards and forming an open flat continuous mat. Numerous plants of *Celmisia verbascifolia* grow through the grass their leaves no longer erect but hanging downwards (Plate XLVII, Fig. 68). Drier cliff is occupied by a combination of *Blechnum* *capense*, *Phormium Cookianum* and *Coriaria angustissima* to be replaced as more soil accumulates, or where the cliff is less steep, by a shrub-association of *Gaya Lyallii*, *Aristotelia racemosa*, *Fuchsia excorticata* and *Veronica salicifolia*.

Rocks rising out of subalpine herb-field, standing on old moraine or forming steep buttresses, ear early on more or less covered with peat and bear a vegetation of many of the species from the adjacent herb-community and a few that are more truly rock-plants. These latter include *Hymenophyllum multifidum* (epharmonic form with curled leaf-segments), the grass *Microlaena Colensoi*, the prostrate shrubby *Dracophyllum Kirkii* (Western district), *Anisotome pilifera*, *Aciphylla Monroi*, *Celmisia Walkeri* (Plate XLVII, Fig. 69) and *Leucogenes grandiceps*. The shrubs *Gaultheria rupestris*, *Coprosma serrulata* and *Senecio Bidwillii* are common [1]).

Steeper, shaded, dripping rocks have certain characteristic plants especially: — *Veronica linifolia*, *Myosotis explanata* (E. of Western district), *M. macrantha*, *Celmisia bellidioides* and *Poa novae-zealandiae* together with plants of other formations e. g. — *Schoenus pauciflorus*, *Geum parviflorum* and *Ourisia* (*Colensoi*)?

The higher alpine rocks, if steep, bear a sparse vegetation which will contain some of the following: — *Polypodium pumilum*, *Microlaena Colensoi*, *Agrostis subulata*, *Carex acicularis*, *Ranunculus Buchanani* (Fiord district), *Aciphylla Monroi*, *A. Kirkii* (South Otago), *A. simplex* (North and South Otago), *Anisotome pilifera*, *A. imbricata*, *Hectorella caespitosa*, *Myosotis pulvinaris*, *Veronica Gilliesiana*, *V. epacridea*, *V. Petriei*, *Ourisia caespitosa*, *O. sessiliflora*, *Celmisia ramulosa* (Fiord), *C. Hectori* (Fiord), *C. laricifolia*, *Leucogenes grandiceps*, *L. Grahami* (Mt. Cook), *Raoulia Buchanani* (Fiord), *Senecio bellidioides* and *S. scorzoneroides* [2]).

In Stewart Island almost any of the subalpine species are found on rocks. The only special rock-plants are: *Polypodium pumilum*, *Anisotome flabellata*, *Raoulia Goyeni* and *Leucogenes grandiceps*.

4. Stony Débris Formations.

a. Shingle slip.

The much-jointed greywacke and allied rocks, which comprise the greater part of New Zealand mountains, become so rapidly distintegrated that stone-fragments accumulate to such an extent as to cover the slopes for hundreds

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1) The following are some of the principal herb-field plants of such rocks: — *Coriaria angustissima*, *Acaena Sanguisorbae* var. *pilosa*, *Epilobium chloraefolium*, *E. arcuatum* (Fiord), *Anisotome Haastii*, *Veronica catarractae*, *V. Lyallii*, *Plantago Brownii*, *Coprosma repens*, *Ourisia caespitosa*, *O. sessiliflora*, *Celmisia Sinclairii*, *Helichrysum bellidioides*, *Senecio bellidioides* and *S. scorzoneroides*.

2) Other plants of wet rocks are the following: *Danthonia flavescens*, *D. crassiuscula*, the rush-like *Marsippospermum gracile* (also amongst the large stones), *Cardamine depressa*, *Pachycladon novae-zelandiae* (Otago), *Aciphylla Spedeni* (S. Otago) and in the Fiord district *A. congesta* and *A. multisecta*.

of metres. Here and there jagged masses of much corroded rock jut out from these stone-fields but hardly break the monotone of the vast, grey even slopes which extend from the lower subalpine belt to the mountain-tops. Gullies, often with rocky walls seam the mountain sides, their floors occupied by a stream, its source the base of some great stone-field where all on a sudden water bursts forth.

The stones themselves differ in size but the bulk are generally small, perhaps 5 or 6 cm long by 2 cm broad, though some may be much larger. Those of the upper layer are quite loose and, as the surface is steep, they are liable to slide downwards, considerable breadths, when disturbed, moving en masse. At 30 cm or more from the surface, the ground is more stable and there is generally a good deal of finer débris, sand, and even clay mixed with the coarser stones. Although quite dry on the surface, at a few centimetres depth the substratum is damp, and deeper still ample water, but icy-cold, is available for plants. The special climate of the habitat depends upon extreme exposure to wind; strong radiation of heat from the stones; powerful heating of the stones themselves and, at times, very bright light. Within the space of a few hours the plants are frequently subjected to burning heat and considerable frost, or one hour they may be surrounded by moist air and the next be exposed to a strong, dry wind. Those which are evergreen bear a heavy weight of snow for four months or more. Nor are occasional droughts unknown. It is obvious then that the ecological conditions of shingle-slip are distinctly those of desert, while in addition there is marked instability of surface. This latter character has, in part, led to the occupation of the ground not merely by certain peculiar growth-forms but *by 26 distinct species which do not occur in any other formation.*

Near the edges of the shingle-slip, the stones are far less liable to move, and there is stability sufficient for species other than those adapted to the moving débris to settle down, so that, by degrees, the formation is transformed into fell-field. But *towards such change the actual shingle-slip association contributes nothing*, its members are too far apart and too few to supply appreciable humus to the soil. *The formation is indeed distinct in itself and not a phase in the development of fell-field but a definite vegetation-entity* the origin of which is wrapped in obscurity.

Shingle-slip, in its unstable and typical form, is confined to those mountains of the South Island with a steppe-climate and is most strongly in evidence in the North-eastern and Eastern districts. Where there is abundant rain the conditions for accumulation of débris are unfavourable, while its occupation by non-shingle plants is much more easy. Certain scoria-slopes of the North Island volcanoes are ecologically similar to true shingle-slip. The schist mountains of the N. and S. Otago districts are virtually without shingle-slip.

The species confined to the formation under consideration are as follows: — *Poa sclerophylla*; *Stellaria Roughii*; *Ranunculus Haastii*, *R. chordorhizos*, *R. pauciflorus*, *R. crithmifolius*; *Notothlaspi rosulatum*, *N. australe*; *Swainsona novae-zelandiae*; *Epilobium pycnostachyum*; *Anisotome carnosula*, *A. diversifolia*; *Convolvulus fracto-saxosa*; *Myosotis decora*, *M. Traversii*, *M. Cheesemanii*, *M. Cockayniana*, *Veronica Cheesemanii*; *Lobelia Roughii*, *Wahlenbergia cartilaginea*; *Haastia Sinclairii*, *H. recurva*, *Raoulia cinerea*, *Craspedia alpina*[1]), *Cotula atrata*, *C. Dendyi*.

The following species are also common: *Claytonia australasica*; *Acaena glabra*; *Anisotome filifolia*; *Veronica lycopodioides*, *V. tetrasticha*, *V. Haastii*, *V. epacridea*; *Haastia pulvinaris*. On fell-field approaching shingle-slip, there are, in the S. Otago district, *Ranunculus pachyrrhizus* and *Raoulia subulata*, but the latter is not confined to this district.

Most of the special shingle-slip plants have important features in common and several bear a close resemblance to one another. Eighteen of the 26 are much the same colour as the stones. All have thick, fleshy or coriaceous leaves which in 24 species are in rosettes. Underground stems, more or less strongly developed, occur in 18 species, while in about 13 the aereal portions are annual. With one or two exceptions, the aereal parts of the plants lie close to the stones, and, although this leads to their being buried, the stems have the power of again growing upwards, while the leaf-texture of many is protective against damage by rolling stones. Generally, the roots, in part, extend horizontally and, in part, descend deeply. Fifteen species are glabrous; on the other hand, the 2 species of *Haastia* and *Craspedia alpina* are densely woolly, the latter with its long, snow-white wool being specially noticeable. *Raoulia cinerea* and the 2 species of *Haastia* are semi-woody. *Wahlenbergia cartilaginea* somewhat resembles a European crusty saxifrage. The 2 species of *Notothlaspi* are probably biennial.

Shingle-slip association of the dry South Island mountains. The plants occur only here and there, indeed one may examine a steep shingle-slip for hundreds of metres and find none or at best a solitary plant or so of *Stellaria Roughii*, *Anisotome carnosula*, both the colour of the stones, or the greener *Cotula atrata*, most noticeable when in bloom with its black flower-heads and golden stigmas. On a more gentle slope with finer débris additional species[2]) appear so that most may be present, though merely dotted about at wide intervals.

Haastia pulvinaris association. This association is characteristic of the alpine belt of the North-eastern district, and it extends for some distance into the North-western district. *H. pulvinaris* is of exactly the same cushion-form as the other great vegetable-sheep, *Raoulia eximia*, already described (Plate XLVIII,

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1) Perhaps this species is not an obligate shingle-slip species for certainly forms greatly resembling it, it not actually identical, occur in fell field.

2) *Ranunculus pauciflorus* and *Myosotis decora* have only been recorded from the Trelissick Basin (Eastern district); with them. on fairly stable ground grow *Lepidium sisymbrioides*, *Carmichaelia Monroi* and *Senecio lautus* var. *montanus*. *Convolvulus fracto-saxosa*, *Wahlenbergia cartilaginea* and *Myosotis Cockayniana* are confined to the North-eastern district and *M. Cheesemanii* to the North Otago district.

Fig. 71), but the shoots are much thicker and the leaves larger and more woolly. The great pale-yellow cushions 2—3 m long and 60 cm or more thick may dot the shingle-slip as far as the eye can reach. The larger examples grow amongst the biggest stones but certainly, in many cases, are not attached to the underlying rock. They do not seem to grow on the finer débris. They are usually much longer than broad, and this is accentuated by the sliding stones from above piling up against them so that the upper surface may be partially buried. Many deaths take place from such burials. Various species are epiphytic on the cushions especially, — *Danthonia flavescens*, *D. semi-annularis* var. *setifolia*, *Celmisia spectabilis* and *C. viscosa*.

Wet Mountain South Island Shingle-slip. Nearly all the characteristic shingle-slip species are absent and various herb- or fell-field plants are present especially, — *Podocarpus nivalis*, *Acaena Sanguisorbae* vars., *Epilobium glabellum*, *Oxalis magellanica*, *Geranium microphyllum*, *Cotula pyrethrifolia*, *Celmisia Sinclairii* and great sheets of *Leucogenes grandiceps* (Western district), *Haastia Sinclairii*, *Veronica Haastii* var. *macrocalyx*, *V. Cheesemanii* and *Epilobium rubro-marginatum*. The last three are virtually true shingle-slip species.

Scoria Slopes on North Island Volcanoes. The scoria slopes of the Volcanic Plateau, and Mount Egmont, present conditions quite as severe as true shingle-slip and, as on certain slopes of Mount Ngauruhoe, may be without plant-life. But there are often a few species distantly dotted about especially: *Luzula Colensoi*, *Claytonia australasica*, *Gentiana bellidifolia* [1]) *Anisotome aromatica*, *Poa Colensoi* and *Gaultheria rupestris*. The most characteristic plant of Ruapehu etc. for this station is *Veronica spathulata* [2]). (Plate XLIX Fig. 72).

b. River-bed.

River-bed has already been described at some length for the lowland and montane belts. The physiographical and ecological conditions as there indicated match closely those of subalpine river-bed, so far as the larger rivers are concerned, except just at their glacier sources. Even the species are much the same, as is the procession of events in plant-colonization. Such differences, as there are, arise from the climate and the colder water of the substratum, while certain species, according to locality, are present which do not descend to or are rare in the lowland belt. Lowland river-bed of the Western district however approximates closely to that of the mountains.

The species, omitting those of fell-field or herb-field which occur in the upper torrent beds, number about 60 which belong to 21 families and 34 genera. Only 8 of the species are actually confined to the mountains but most of them descend to the montane belt. As in the lowlands, the most important mem-

1) Not on Egmont.

2) A prostrate subshrub which forms a mat of numerous flexible decumbent stems provided with numerous, small, thick, bright-green leaves covered with small white hairs. The root descends deeply and is of extraordinary length.

bers of the formation are the species of *Epilobium* and *Raoulia*[1]) with *E. melanocaulon* characteristic of the dry areas and *E. glabellum* of the wet. Other common species are the grey, low shrub *Helichrysum depressum* half-dead looking with rigid stems and scanty small appressed leaves; great circular mats of *Muehlenbeckia axillaris*; several species of *Acaena*; *Veronica Lyallii* in the wet and *V. Bidwillii* in the dry areas or stations; *Helichrysum bellidioides*, *Coriaria thymifolia*; *C. angustissima* (where abundant rain), *Veronica catarractae* (Fiord district), *Angelica montana*, *Discaria toumatou* and *Raoulia glabra*. *Raoulia Haastii*, which forms large green cushions, is the characteristic plant of many river-beds in the Eastern and Western districts and occasionally occurs in the South Otago district.

Subalpine torrent beds of the wet mountains, especially near their sources contain more or less of the fell-field and herb-field species and their open plant-covering may resemble that of the adjacent fell-fields. So, too, the old bed of the wider valleys often has a considerable florula and the association may be closed, but it is generally rather steppe dotted with shrubs than fell-field. *Veronica buxifolia* var. *odora* and *Carmichaelia grandiflora* are common in this association in the drier central Southern Alps.

c. Fan.

In the drier mountain areas, more especially, where gullies or gorges open out on to plain or river bed, there are fans of débris, sometimes of great size. Their vegetation depends upon the supply of stones brought down by the torrent and this again is correlated with the age of the gully and the plant-covering of its walls. Fans may be either active or passive, and every transition between the two can be seen. The stony surface is much steeper than that of river-bed in general. There are water-channels but these are usually dry except during heavy rain, the actual stream running underground. Many of the stones are large and much of the débris coarse and piled up into comparatively high but quite unstable terraces liable during flood to damage or absolute destruction.

The vegetation is that of river-bed and commences with the usual species of *Epilobium* and *Raoulia*. Finally tussock steppe or Discaria scrub may be established but the intermediate stage may possess many circular mats of *Muehlenbeckia axillaris* and extensive colonies of the ferns *Blechnum penna marina* and *Hypolepis millefolium*.

5. Grass and Herb Formations.

a. General.

The distinction between grass and herb formations may seem at first thought arbitrary, since there are none of the associations that do not contain

1) *E. pedunculare*, *E. glabellum*, *E. melanocaulon*, *E. microphyllum*, *E. rostratum*, *E. macropus*, *R. tenuicaulis*, *R. Haastii*, *R. glabra*, *R. australis*, *R. Parkii* (where the climate is specially dry) and *R. lutescens*.

plants of both classes, while grass-tussock is frequently a common feature of herb-field. Still the distinction is ecologically sound, because dominance of grass in primeval New Zealand denotes a far stronger xerophily than does that of herbs and the two opposing formations, steppe[1]) and herb-field, are essentially expressions of climate. On the other hand, the distribution of fell-field is, in part, due to edaphic causes, and the formation might with some propriety, but much less convenience, have been dealt with under the heading of débris.

Although the formations under consideration are each of a definite ecological character throughout their range in New Zealand, there are many different combinations of species in passing from N. to S., or from dry to wet areas. There are also often great differences between mountains in close proximity, so that it is impossible, in a brief account, to include all details, even were such known. Here, at best, a general and broad view is attempted, especially such as may bring out the salient features both with regard to distribution and ecological distinctions.

b. Tussock steppe.

The general remarks as to grassland in Section 11 apply here also, except that tall steppe is not specially, as in the lowlands, a mark of sour ground but rather of higher altitude. The various associations with few exceptions are far from being virgin, but the number of introduced plants is far less than in the lowlands. Frequent burning and overstocking, however, have in certain localities, especially the North Otago district, changed the formation altogether turning it into actual desert.

1. Low tussock steppe (Poa-Festuca tussock-grassland association).

This formation up to an altitude of 600 m, or more, has already been dealt with when treating of the lowland vegetation. At above that altitude certain of the higher mountain species appear, changing to some extent, or considerably, the general facies. Most important in this regard are the *Yucca*-like *Aciphylla Colensoi*[2]) with its yellowish, erect bayonet-like leaves, 40 cm high, and the low, green circular cushions of *Celmisia spectabilis*, 90 cm in diam. The species enumerated for montane steppe are mostly present and in addition the following may be cited: *Blechnum penna marina*, *Hypolepis millefolium* (where stony), *Lycopodium fastigiatum*, *Ophioglossum coriaceum*, *Danthonia Buchanani* (especially in the North Otago district), *Koeleria novo-zelandica*, *Poa Kirkii*, *Poa Lindsayi*, *Uncinia rubra*, *Phormium Cookianum* (in shaded or moist places), *Chrysobactron Hookeri*, *Muehlenbeckia axillaris*, *Stellaria gracilenta*,

1) It seems much better to call the tussock formations of New-Zealand "tussock-grassland" rather than "steppe", and this is the name given in my recent writings. For further remarks on this point see the Preface.

2) In the primitive association this formed great thickets impassable to horsemen. The *Celmisia*, on the contrary, has increased considerably through the tussock being burned.

Ranunculus Monroi var. *dentatus* (mountains of the Eastern district), *Acaena inermis*, *A. microphylla*[1]), *Viola Cunninghanii*, *Drapetes Dieffenbachii*, *Epilobium elegans*, *Hydrocotyle novae-zelandiae*, *Anisotome aromatica*, *Gaultheria depressa*, *Pernettya nana*[2]), *Dracophyllum uniflorum* (dotted here and there and rising above the tussock), *Styphelia Colensoi*, *Gentiana corymbifera* (abundant in many places and very handsome with its numerous large white flowers raised on a stout peduncle 30 cm high), *Myosotis australis* (flowers yellow), *Veronica pimeleoides* var. *minor* (stony ground, flowers blue), *Coprosma Petriei* (forming a continuous turf of several square metres in extent), *Celmisia discolor* agg., *Helichrysum bellidioides*, *Raoulia glabra*, *Cassinia Vauvilliersii*, *C. fulvida* (these two latter dotted about or making patches), *C. albida* (North-eastern district) and *Taraxacum magellanicum*. *Festuca novae-zelandiae* is easily dominant.

2. Red tussock (*Danthonia Raoulii*[3]) steppe.

Volcanic Plateau. *D. Raoulii* steppe clothes much of the pumice-scoria soil, as already described for shrub-steppe, on the Volcanic Plateau where forest is wanting at an altitude of 9—1200 m. The tussocks, some 75 cm high, are usually a metre or more apart, but in places they touch. *Celmisia longifolia* var. *gracilenta* (silvery in colour) is abundant. Erect, dark-coloured, fastigiate bushes of *Dracophyllum subulatum*, 45 cm high, affect the general physiognomy. There are also circular mats of *Coprosma depressa*, cushions 90 cm in diam. of *Celmisia spectabilis*, the small but beautiful *Euphrasia tricolor*, large flat glaucous mats of *Celmisia glandulosa*, bluish-green patches of *Pentachondra pumila*, *Gaultheria depressa*, *G. perplexa*, *Styphelia Fraseri*, *S. Colensoi*, *Danthonia semiannularis* var. *setifolia*, *Poa anceps*, *Hierochloe redolens*, *Agropyron scabrum*, *Poa caespitosa* and *Lycopodium fastigiatum*.

Mount Egmont. The vegetation above the scrub-line is made up of grasses, herbs, shrubs and mosses. Herb, grass or moss may dominate in places and portions of the plant-covering might with propriety be designated herb-field or fell-field according to whether closed or open. Here on account of the dominance of *Danthonia Raoulii*, in many places, I am classing the whole with steppe. By the settlers of Taranaki, the formation is invariably spoken of as the "Moss", so that one might gather that flowering plants were absent. Certainly large white cushions of the xerophytic *Rhacomitrium* (*lanuginosum*)? give a most characteristic aspect to the scene. These cushious are dense, rounded and not unlike *Sphagnum* hummocks or vegetable-sheep. They are

1) Though common everywhere there is an extraordinary abundance of this species in various forms on the montane steppe near lakes Wakatipu, Te Anau and Manapouri which is most conspicuous in early autumn with the bright red spines to the calyx.

2) Local in its distribution, but where it occurs often forming almost pure patches of considerable extent. It also grow in quite wet ground in the South Otago district.

3) The species here called *Danthonia Raoulii* is *D. Raoulii* var. *rubra* of my recent writings in the N.Z. Journ. of Agriculture. *D. flavescens*, dealt with further on may eventually prove to be either the "type" of *D. Raoulii* or much nearer to that than is var. *rubra*.

raised noticeably above the level of the floor and perhaps average about 70 cm long by 60 cm broad and 10—12 cm deep; when dry, the colour is greyish-white on account of the numerous dry hairs, but when moist they have a greener shade. The cushions may join and form amorphous masses or they may be separated by a carpet of herbs. Within, the moss is dead and full of moisture. Usually some of the carpet plants much buried by the moss grow as epiphytes, but they fail to obtain complete possession. On some parts of the mountain these moss-cushions are absent and, in their place, are abundant patches of a yellowish-green moss.

Tussocks of *Danthonia Raoulii* are abundant. Brown bushes of *Dracophyllum filifolium*, about 12 cm high, form broad, erect patches perhaps 60 × 40 cm in area. Flat-topped yellowish cushions of the shrub *Cassinia Vauvilliersii* 17 cm high and 27 cm in diam., are common, and there are many small bushes of *Veronica buxifolia* conspicuous with its bright-green leaves and bare, leaf-scarred stems. Everywhere, in January, the plant-covering is marked by the beautiful white whorls of flowers of *Ourisia macrophylla*, 27 cm or so high rising from the rosettes of pale-green, purple-edged leaves.

The groundwork of the association consists principally of the following low-growing herbs and shrubs: — *Hymenophyllum multifidum*, *Lycopodium fastigiatum*, *Danthonia semiannularis* var. *setifolia*, *Anisotome aromatica*, *Gaultheria depressa*, *Coprosma repens*, *C. ramulosa*, *Forstera Bidwillii*, *Celmisia longifolia* var. *major*, *C. glandulosa*, *Raoulia glabra*, *Helichrysum bellidioides* var. *prostratum* and *Cotula squalida*.

At about 1300 m altitude, *Ranunculus nivicola* becomes abundant, its golden-yellow flowers giving a special stamp to the association. *Drapetes Dieffenbachii* appears and soon becomes a most important member of the turf; the shrubs and the tussock gradually gives out; *Celmisia longifolia* var. *major* becomes, in places so abundant as to form silvery patches; and *Poa Colensoi* becomes of moment. This association might quite well be called herb-field. Its presence depends upon a much longer covering of snow than that to which the tussock is subjected. Gradually, it gets more and more open, as the altitude increases, until there is the scoria-vegetation already described under the heading "shingle-slip"[1]).

The South Island Mountains. Red tussock steppe in the South Island denotes a colder or wetter situation than low tussock steppe. In the South Otago district it may be continuous with that of the lowland and montane belts but further N. it rarely descends much below 600 m altitude. *Sphagnum* moor is readily occupied by *Danthonia Raoulii* and so turned into steppe. In some places it replaces low tussock-steppe at a higher altitude. The species

1) The following species are also more or less common: *Oreobolus pectinatus*, *Luzula campestris* var., *Blechnum penna marina*, *Hydrocotyle novae-zelandiae*, *Geranium microphyllum*, *Oreomyrrhis andicola* var., *Epilobium chloraefolium*.

are much the same as those of low tussock steppe for the same locality. Since *D. Raoulii* is less relished by grazing animals than other tussock-grasses, its present distribution may in some instances not be a natural one.

3. Mountain tussock (*Danthonia flavescens*) Steppe.

Danthonia flavescens is a more robust and broader-leaved grass than *D. Raoulii* and forms large tussocks up to 1.5 m high, or more. The association, when fully developed, may consist of little else than a dense green mass of tussocks not easy to penetrate. This has led to the destruction of the original association in many places through periodical burning by musterers in order to make paths for bringing down the sheep from the alpine pastures. At the present time, the tussock-grassland under consideration is to be seen at its best on the wet mountains of the South Island, especially in the South Otago botanical district. But even on the much drier mountains of the North Otago district it is not wanting.

Usually *Danthonia flavescens* steppe forms a belt commencing at from 900 to 1250 m altitude and extending upwards for some 300 m more or less, when it may be succeeded, on certain mountains, by low tussock steppe composed principally of *Poa intermedia*. In some localities, however, an association with *D. flavescens* dominant occurred in primitive New Zealand at a much lower altitude. Thus, on the table-land extending from the Lammermoor Mountains to the gorge of the R. Taieri (with a maximum altitude of 600 m) there is every indication that most of the surface was occupied by *D. flavescens* accompanied by abundance of *Aciphylla Colensoi*. As a good example of the tall tussock steppe now being considered that of the Hector Mountains (South Otago district) may cited. The tall tussock belt begins at about 1100 m altitude. In many places the tussock is extremely dense. *Aciphylla Colensoi* is abundant; there is a good deal of *Chrysobactron Hookeri*. The following species are fairly common: *Calamagrostis avenoides*, *Agrostis Dyeri*, *Poa intermedia*, *Festuca novae-zelandiae*, *Gentiana corymbifera* (or an allied species), *Wahlenbergia albomarginata*, *Celmisia coriacea*, *C. Lyallii* and *Helichrysum bellidioides*. At its upper limit (1320 m) the *Danthonia* tussocks become scattered and *Poa intermedia* becomes dominant, while many of the higher-mountain plants put in an appearance, e. g.: *Carex wakatipu*, *Epilobium tasmanicum*, *Coprosma repens*, *Phyllachne Colensoi*, and *Raoulia grandiflora*.

In winter, notwithstanding the great size of the *Danthonia* tussocks they are flattened to the ground by the snow and are frequently not uncovered until the beginning of December, or even later.

4. Some local associations.

a) *Triodia exigua steppe*. *T. exigua* is a small turf-making grass spreading extensively by means of its long, much-branching rhizomes which form a matted tangle. The leaves are narrow, about 2.5 cm long, filiform, stiff and almost pungent. Where dominant, there is a close, dense sward looking almost as if regularly mown. Certain other quite low-growing plants, mostly with creeping underground stems, grow in this association, e. g. — *Triodia pumila*, *T. Thomsoni*, *Carmichaelia nana*, *C. Enysii*, *C. uniflora* (one or other of the three), *Styphelia Fraseri* and *Wahlenbergia albomarginata*. The association occurs from the North-eastern to the North Otago districts.

β) *Dwarf Carmichaelia steppe*. This has been already described for the lowlands. Is occurs on very stony, dry ground, notably ancient river-bed. One or other of the species of *Carmichaelia* noted above is dominant forming broad patches of short, flat, erect green stems. There may also be present more or less prostrate *Discaria toumatou*, round mats of reddish-leaved *Acaena inermis*, the close turf-making suffruticose *Coprosma Petriei*, *Wahlenbergia albomarginata*, low, flat, silvery cushions of *Raoulia lutescens* and probably *R. australis*. The association occurs throughout the drier mountain valleys of the South Island.

γ) *Poa acicularifolia association*. So far *P. acicularifolia* has been recorded only from the Mount Arthur Plateau (North-western district) and the Trelissick Basin (Eastern district), growing in both localities on limestone soil[1]). The grass itself is much branching and forms close flat leafy cushions, or patches, 7—15 cm in diam. The leaves are 4—8 mm long, involute, curved, rigid, smooth and sharp-pointed. The closeness of the grass-cushions is in proportion to the stoniness of the ground, the plant thriving on consolidated shingle-slip. The neighbouring tussock-steppe plants or semi-shingle-slip species enter into the association.

δ) *Carpet-grass* (*Danthonia australis*) *steppe*. This remarkable association is confined to the alpine belt of the North-western, the wettest part of the North-eastern and the N. of the Eastern districts, where it may cover the mountain-side for many square metres, or, where the conditions are unfavourable, make merely small patches.

D. australis forms dense mats 5 cm or so thick. Beneath, there is much dead grass. The culms and leaves are flattened to the ground and all point one way. The stem is creeping, slender, much-branched and covered thickly for 10 cm or more with old leaf-sheaths. At this point, quite short roots are put forth, but longer ones, 6—7 cm in length pass off from the base of the leafy stems. The leaves have broad sheaths almost equalling the blades. The latter are stiff, hard, wiry, closely involute, smooth, polished, 2.5—5 cm long, needle-like, rather sharp-pointed.

The mats form a slightly hummocky dense covering to the ground quite slippery when walked on. The closeness of growth is antagonistic to other plants, the most important of which are flat cushions of *Celmisia spectabilis*, *C. viscosa*, *C. Lyallii* and *C. intermedia* according to the locality. Here and there are a few tussocks of *Danthonia flavescens* or in some localities *D. cras-*

1) A closely allied plant, perhaps a variety of this species, is common on the magnesian soil of the Mineral Belt of Nelson. The type has also recently been noted in eastern Marlborough.

siuscula. Where there is a little open ground a few fell-field species, e. g. — *Pimelea Lyallii* var., *Veronica lycopodioides*, *Aciphylla Monroi*, *Celmisia laricifolia* &c., may be present, but are not really a part of the association.

c. Fell-Field.

1. General.

Fell-field is found in the upper subalpine and alpine belts, its greatest development being on the dry greywacke mountains of the South Island. The vegetation is always open, the area of bare ground, — stony, clayey or sandy —, being frequently much greater than that occupied by plants. Although apparently a strictly edaphic formation, yet the requisite substratum can only be formed in a climate favourable for the disintegration of rock and soil, while such a climate is unfavourable for all plants except more or less extreme xerophytes.

The disintegration constantly in progress renders the formation far from long-lived, the vegetation being in a constant state of destruction and renewal. A heavy snowfall is before all else the most powerful factor for damage, on a large scale, since it leads to snow avalanches which tear up the surface destroying all vegetation and depositing the remains on the gully-floor hundreds of metres below. Further, in the struggle between climate and plant-colonization, the former has now most powerful allies in the shepherd's fires and sheep, together with the rabbit-pest and the various animals introduced for sporting purposes. Seeds germinate well enough, when they get the chance, and in New Zealand at any rate it is not as Warming suggests (1909: 256) a relation between seed-germination and climate that determines the openness of fell-field, but altogether the disintegration factor.

In some respects the ecological conditions resemble those of shingle-slip, but there is the great distinction of temporary stability of the substratum. Probably the water-content of the soil is less, especially where clayey. There are frequently flat places and hollows, where snow collects, and in such, owing to the better water-supply, are oases of closed vegetation, some of whose species do not occur on fell-field proper. Large stones and rocks, a common feature (Fig. 73), afford shelter and shade, and supply a special station. So too, the banks of streams, or spots where water oozes from beneath the stones.

The species for fell-field throughout New Zealand number about 209, which belong to 35 families and 76 genera, the most important of which are: — *Celmisia*, *Ranunculus*, *Aciphylla*, *Veronica*, *Carex*, *Poa*, *Danthonia* and *Epilobium*. No fewer than 146 of the species are confined, or virtually so, to the high mountains. Many species too are of local and restricted distribution, so that perhaps 100 might be considered a fair average for a high mountain.

Coming now to ecological details, all the species are evergreen except 6 (summer-green) and 1 (annual). Shrubs number 27, grass-like plants 39 and ferns &c. 3. No fewer than 157 (74 %) are of very low stature, most of them being prostrate plants, many of which have creeping underground stems, while some 72 virtually hug the ground. There are 32 cushion-plants, the majority low and flat. As for the erect plants, 10 are tussocks and 15 have extremely rigid leaves or stems. There is, in fact, throughout the fell-field vegetation a striking adaptation against the action of wind in its widest sense. Regarding the leaves, those of 141 species are quite small, while 4 species are virtually

Fig. 73. *Helichrysum bellidioides*, fell-field, Tararua Mts. Ruahine-Cook district. Photo E. Bruce Levy.

leafless. Almost all have coriaceous, thick, hard or stiff leaves. Where the leaves are comparatively large, they are either thick, stiff and intensely rigid (*Aciphylla*), thick, coriaceous and in rosettes (certain species of *Ranunculus*) or covered beneath with dense tomentum (*Celmisia*). Even quite small leaves in species of conspicuously dry stations are often tomentose or strongly hairy, but glabrous species occupy similar stations and hairiness of moment occurs only in 57 species (27 %), 37 of which are *Compositae*.

2. Special Details.

α. The Dry Mountains of the South Island.

Viewed from a lofty eminence in the North-eastern district, grey mountain slopes in all directions meet the eye apparently quite devoid of vegetation, indeed nothing could appear more desert-like. To be sure, not all the dry mountains look so barren as the above, but they rarely possess anything like a continuous covering throughout the alpine belt, but show, at best, vast débris-fields divided by narrow triangular lines or strips of vegetation which converge towards the brown steppe or dark forest. Such lines, or patches, raised slightly above the general level stand out from the desert of unstable stones. A closer view shows that there is rarely a continuous plant-covering. Patches of clayey, stony soil, large or small, abound containing some times the remains of dying plants the long roots exposed, but rarely in process of occupation.

The soil is of diverse origin and may be stones merely (e. g. consolidated shingle-slip), loess, glacier-clay or clay from underlying rock. It is obvious, that through unstability of the substratum, these must frequently be mixed together. As plant-colonization proceeds, a variable amount of humus accumulates and the soil becomes loamy. The water-content varies much according to the season of the year and to position with regard to the sun, a certain average of shade favouring closed vegetation, if the number of rainy days be sufficient.

The most important physiognomic plants are, — certain shrubs (especially prostrate *Podocarpus nivalis* and low bushes of *Dracophyllum uniflorum*), flat low cushions of several species of *Celmisia* (*C. discolor* agg., *C. intermedia*, *C. spectabilis* and *C. viscosa*), tall erect rosettes of other species of that genus (*C. Lyallii*, *C. pseudo-Lyallii*), tussock-grasses (*Danthonia flavescens*, *D. Raoulii*) and the *Yucca*-like *Aciphylla Colensoi*. The *Dracophyllum* gives a brownish colour to the hillside at an elevation of from 9—1200 m, and is conspicuous from a considerable distance. *Podocarpus nivalis* forms yellowish mats several square metres in extent; it is an early comer and characteristic of the most exposed stony ground subject to full insolation and violent winds. The leafless yellowish, trailing shrub *Exocarpus Bidwillii*, low dark cushions of the divaricating-shrub *Hymenanthera dentata* var. *alpina* (Fig. 74), small hard-leaved plants of *Gaultheria rupestris* and the glaucous-leaved species of *Veronica*, with prostrate gnarled black stems and imbricating leaves crowded near the ends of the branches, are all plants of particularly dry and exposed stations. Other shrubs of dry ground are: — *Carmichaelia Monroi* (forming open, low cushions of short, broad, leafless, rigid, flat stems) *Styphelia Colensoi* (dark-coloured mats), prostrate *Dracophyllum rosmarinifolium*. On certain mountains from the North-eastern to the North Otago district is the remarkable *Corallospartium crassicaule*, an intensely xerophytic shrub with a stout, rigid, sparingly-branched, yellow grooved stem, 1 m or more high, and about 2 cm in diam.

The abundance of the herbs and subshrubs, nearly all prostrate or low-growing plants, depends upon the degree of moisture in the soil. Where dry, but few species are present, especially, — *Scleranthus biflorus*, *Muehlenbeckia axillaris*, *Colobanthus Billardieri*, *Acaena inermis*, *A. Buchanani* (Central Otago and Mackenzie Plain), *Geranium sessiliflorum* var. *glabrum*, *Pimelea Lyallii* agg., *P. sericeo-villosa* (North-eastern to North Otago), *Drapetes Dieffenbachii*, *Hydrocotyle novae-zelandiae* var. *montana*, *Pratia macrodon*, *Helichrysum bellidioides*, *Cotula pyrethrifolia*, *C. pectinata* and *Senecio lautus* var. *montanus*.

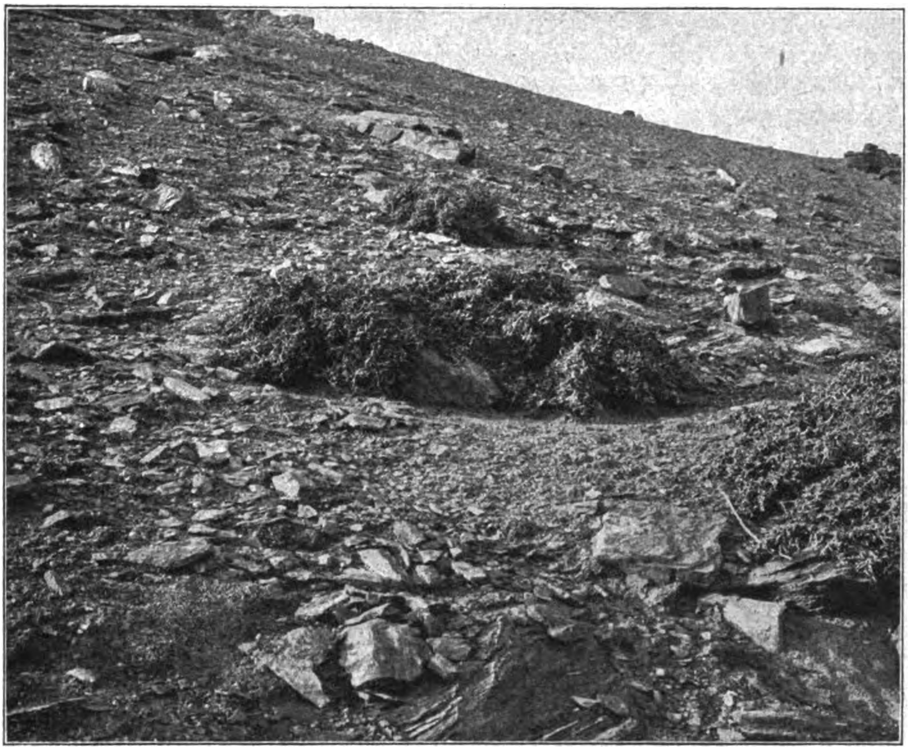

Fig. 74. *Hymenanthera dentata* var. *alpina* growing on rock, Dunstan Mts., North Otago district at about 270 m altitude in depleted ground originally grassland. Photo L. Cockayne.

Moister places, especially where shaded, contain a richer vegetation, which of course may include many of the above. Green mats of *Ourisia caespitosa* (showy when one mass of white blossom) are characteristic. The following may also be present: *Ranunculus Enysii*, *R. Monroi* or var. *dentatus*, *R. multiscapus*, *R. Sinclairii*, *R. gracilipes*, *R. geraniifolius* (North-western district), *Geum parviflorum*, *Geranium microphyllum*, *Oxalis magellanica*, *Viola Cunninghamii*, *Drapetes Lyallii*, *Epilobium pedunculare* var., *E. chloraefolium*, *Schizeilema hydrocotyloides*, *Oreomyrrhis andicola* agg., *Anisotome aromatica*, *Gentiana patula*, *Myosotis pygmaea*, *Veronica Lyallii*, *V. Bidwillii*, *Euphrasia Monroi*, *E. revoluta*, *E. zealandica*, *Plantago Brownii*, *Coprosma repens*, *Wahlenbergia albomarginata*, *Forstera sedifolia*, *F. Bidwillii*, *Craspedia* (one or other of the species), *Senecio bellidioides* and *Taraxacum magellanicum*.

At a variable altitude, but say at about 1200 m, the vegetation changes and the *alpine belt* begins. The principal sign is the appearance of great mats of the stiff-leaved *Celmisia viscosa* and the rather thin-leaved *C. Haastii*. The ground in many places is extremely stony being really consolidated shingle-slip. Several small cushion-plants are characteristic of these stony stations, e. g. — *Luzula pumila* and its allies, *Myosotis pulvinaris* (5—10 cm in diam.), *Veronica pulvinaris* (North-western to Eastern district), *V. ciliolata* (local in the North-western and Eastern districts), *Phyllachne clavigera*, *P. Colensoi*, *Celmisia laricifolia* and *Raoulia grandiflora* (see Plate L, Fig. 75).

Grasses play a considerable part in the formation at all altitudes. The tussocks already mentioned, *Danthonia semiannularis* var. *setifolia*, *Poa Lindsayi* (a plant of the driest stations) *Poa Colensoi* and *P. intermedia* are the most important.

β. The wet mountains.

On the wet mountains of both Islands fell-field is almost confined to the alpine belt. Such herb-field species as can tolerate stony ground and a snow-covering for several months are present.

Stony ground near the summits of the highest peaks of the Tararua Mts. contains an open vegetation consisting of, — *Danthonia flavescens*, *Ranunculus insignis*, *Anisotome dissecta*, *Veronica Astoni* (cupressoid), *Phyllachne Colensoi*, stunted *Celmisia hieracifolia*, *Leucogenes Leontopodium* (Plate No. L, Fig. 76) and *Raoulia grandiflora*.

The wet mountains of the South Island contain, in their alpine belt, a much richer vegetation than do the dry mountains and species far more striking. Of such the following *Ranunculi* are particularly noteworthy: *R. insignis* (North-western district), *R. Monroi* (North-western and North-eastern to Eastern district), *R. sericophyllus* (Western and Fiord districts), *R. Godleyanus* (Southern Alps from Rakaia Basin to beyond Franz Josef Glacier), *R. Buchanani* (Fiord), *R. pachyrrhizus* (local, South Otago district), *R. Matthewsii* (Fiord) and *R. Baughani* (Fiord). Certain of these species which also grow in herb-field are much dwarfed. Other characteristic plants are: *Marsippospermum gracile* (stiff tussock 20 cm high), *Microlaena Colensoi*, *Uncinia macrolepis*, *U. fusco-vaginata*, *Acaena Sanguisorbae* (many varieties), *Coriaria angustissima*, *Viola Cunninghamii*, *Carmichaelia grandiflora*, *Epilobium glabellum*, *E. rubro-marginatum*, *E. tasmanicum* agg., *Aciphylla Monroi*, *A. Kirkii* (South Otago and Fiord), *A. Lyallii*, *A. Hectori* (Fiord), *Dracophyllum Kirkii*, *Suttonia nummularia*, *Veronica macrantha*, *Ourisia sessiliflora*, *O. prorepens* (Fiord), *O. glandulosa* (South Otago and Fiord), *Phyllachne Colensoi*, *P. clavigera*, *Celmisia sessiliflora* (the silvery cushions are a striking feature of many mountains of the Western district), *C. argentea*, *C. Sinclairii*, *C. ramulosa* (Fiord), *Leucogenes grandiceps*, *L. Leontopodium* (North-western district), *Cotula pyrethri-*

folia, *Raoulia Hectori* (South Otago and S. of Western district on the east), *Senecio scorzoneroides* and the shrubby *S. revolutus* forming wide, flat mats.

d. Herb-Field.

1. General.

Herb-field occurs on all the high mountains subject to frequent rain and where the climate is less favourable for the disintegration of rock and soil than on the dry mountains but much more favourable for the making and accumulation of raw humus or peat. Where fully developed, the members grow closely and there is no bare ground, but there is every transition in this regard from herb-field to fell-field. The water-content of the soil is a factor of much moment, there being two distinct types of herb-field, "*dry*" and "*wet*", the latter closely related to moor while the former, where tall tussock dominates, outwardly resembles steppe (tussock-grassland).

The formation, especially dry herb-field, is less xerophytic than fell-field, indeed certain characteristic members are mesophytes distinguished by large, glabrous leaves (*Ranunculus Lyallii*, *Ourisia macrocarpa* vars. *calycina* and *cordata*, *Anisotome Haastii*). Even species with marked xerophytic structure can develope leaves of considerable size (*Celmisia coriacea*, 60 × 7 cm, *Aciphylla maxima*, 1.5 m long).

Herb-field occurs in the North Island on the main range from the highest peaks of the East Cape Mts. southwards; and, in the South Island, on both sides of the Southern Alps subject to the western downpour together with the mountains of the North-western district, many in the South Otago district, and those of Stewart Island, but there, for the most part, the formation is that form I am calling "Herb-moor". The vegetation of snow-patches in fell-field is closely related to herb-field.

The formation attains its richest development on the various passes of the Southern Alps (9—1500 m altitude); on the basin-like beds of corries; on the floors and lower slopes of glacier-cirques and on the more gentle mountain slopes in general. Throughout the greater part of the western Southern Alps the vegetation is absolutely virgin.

The special soil-condition, a surface of peat, has been brought about by the plants themselves. Although frequently sopping wet, cessation from rain for a few days, a quite common happening, brings about a striking change for the plants, which is met by their xerophytic adaptations.

The number of species occurring in the formation is about 255, 42% of which also occur in fell-field; they belong to 31 families and 84 genera of which *Celmisia*, *Gentiana*, *Danthonia*, *Ranunculus*, *Aciphylla*, *Epilobium*, *Ourisia* and *Veronica* are the most important.

The growth-forms include 41 shrubs, which, with one or two exceptions, are prostrate; 177 herbs or semi-woody plants; 29 grass-like plants, 2 rush-like and 6 ferns. Cushion-plants number 12; summer-green herbs 14; herbs or grasses, above 15 cm high, 54; and plants with very hairy or tomentose leaves 57.

The most beautiful herbaceous plants of the New Zealand region, those of the Subantarctic province excepted, occur in subalpine herb-field, and, when in full bloom, the highest slopes of the Ruahine-Tararua Mountains, or the virgin passes of the Southern Alps, where alpine and subalpine vegetation mingles, are lovely natural gardens (Plate LI, Fig. 77).

2. Dry Herb-field.

α. Mount Hikurangi (East Cape district, North Island).

Aciphylla Colensoi and *A. squarrosa* are dominant. The following is a list of the species according to J. ADAMS (1898: 418, 19): *Hierochloe Fraseri*, *Trisetum antarcticum*, *Danthonia Cunninghamii*, *D. semiannularis* var. *setifolia*, *Poa caespitosa*, *P. anceps*, *P. Colensoi*, *Oreobolus pectinatus*, *Schoenus pauciflorus*, *Uncinia compacta*, *Ranunculus insignis*, *Coriaria angustissima*, *Epilobium glabellum*, *Oreomyrrhis Colensoi*, *Pentachondra pumila*, *Gentiana bellidifolia*, *Myosotis pygmaea*, *Celmisia spectabilis*, *Raoulia grandiflora*, *Leucogenes Leontopodium*, *Craspedia uniflora* and *Taraxacum magellanicum*.

β. The Tararua Mountains.

The peculiar and striking feature of the formation on these mountains is the enormous quantity of *Astelia montana* in clumps 2.5 m × 1.9 m or it may form a silvery and continuous covering for many square metres at a time. In many places *Danthonia Raoulii* or *D. flavescens* are dominant and a steppe-like character results. Very characteristic are the circular clumps of *Ranunculus insignis*, the green leaves contrasting with the equally abundant silvery sheets of *Leucogenes Leontopodium*, which are most lovely when in full bloom with the peduncles closely clothed with appressed silvery bracts and the flower heads 4 cm in diam. with their snow-white flannely bracts. The following conspicuous plants are present in abundance: *Chrysobactron Hookeri*, *Aciphylla conspicua* (noticeable with its orange midrib), *Anisotome dissecta* (a rather tall Umbellifer with finely-cut leaves), flat circular cushions of *Celmisia spectabilis* and *C. hieracifolia*[1]) (Plate LII, Fig. 79). As is usual some of the subalpine-scrub shrubs appear in the association, especially *Coprosma cuneata* and *Veronica evenosa*, but the following belong properly to the combination, — *Gaultheria depressa*, *Dracophyllum rosmarinifolium* and *Veronica Astoni* (cupressoid-shrub, prostrate to rounded bushes 30—60 cm high) *Pimelea Gnidia* (Plate LII, Fig. 80). The following are the more important of the smaller grasses and herbs: *Poa anceps*, *Triodia australis* (forming a turf in some localities), *Ranunculus geraniifolius*, *Oxalis magellanica*, *Epilobium chloraefolium*, *E. Cockaynianum*, *Veronica*

1) There is a stout, woody creeping stem clothed above with a dense covering of old dead leaves. At the ends of the branches are loose rosettes of pliable linear-oblong, obtuse leaves 12 cm long 2.5 cm broad clothed beneath with smooth, white, papery tomentum. The flower-heads are large and showy.

catarractae, *Ourisia caespitosa* and *Euphrasia cuneata*. The total number of species for the association is about 53 [1]).

γ. Mount Stokes (Marlborough Sounds).

The isolated position of the mountain 1200 m high and its geographical situation render it of peculiar interest. For what follows I am indebted to Mr. E. PHILLIPS TURNER and Major A. A. DORRIEN SMITH. On the summit of the mountain there is a small expanse of herb-field the chief members of which are: — *Danthonia Raoulii*, *Poa Colensoi*, *Phormium Cookianum*, *Astelia montana*, *Chrysobactron Hookeri*, *Ranunculus geraniifolius*, *Acipyylla Colensoi*, *Gaultheria rupestris*, *Styphelia empetrifolia*, *Pentachondra pumila*, *Pimelea Gnidia*, *Celmisia hieracifolia*, *C. Rutlandi* [2]) and *Cassinia Vauvilliersii*.

δ. South Island Mountains in general.

It would be impossible, even were anything like exact details available, to put forth in a short general account of the association the relationship between the dominance of this or that plant to soil or topographical conditions. Suffice it to say, that in some places tussocks dominate, in others *Phormium Cookianum* and again, in others, species of *Celmisia* or *Ranunculus*.

The tussocks consist of *Danthonia flavescens*, *D. crassiuscula*, *D. Cunninghamii* and *D. Raoulii*, the latter the most uncommon. The tussocks of *D. Cunninghamii* are 1.5 m high at times, the leaves flat, 7 mm broad and the large panicle very handsome. *D. crassiuscula* often forms an association on flattish ground in the alpine belt where snow lies long, the plants grow closely, the tussock-form is lost and a twisting of the filiform extremities of the rigid, coriaceous leaves gives a curious aspect to the society.

The large species of *Celmisia*, with erect or semi-erect rosettes, frequently form extensive more or less pure colonies. They fall into the two categories of those with wide leaves which, in one class (*C. petiolata*, *C. Traversii* &c.), arch downwards at their extremities and those with narrow stiff leaves (*C. Armstrongii*, *C. Petriei*, *C. lanceolata* &c.). *C. coriacea* agg. occurs throughout the wet South Island mountains and its broad silvery leaves and great white flower-heads 8—12 cm in diam. render it extremely conspicuous (Fig. 81). Various parts of the Southern Alps possess particular species, and as these are by no means closely alike, they affect the physiognomy to some extent [3]).

1) Estimate from ASTON 1910: 13; PETRIE 1908: 289 and my own observations. Of course this does not include all the plants above the scrub-line.

2) Leaves 15 cm long or longer, rather thin and soft, bright green above but beneath tomentose much as in *C. coriacea*; midrib stout purplish.

3) *C. Traversii* with rusty tomentum and leaf margined with same is characteristic of the northern part of the Southern Alps and neighbouring mountains; it occurs also in the Fiord district. *C. cordatifolia* is found on a few mountains of the North-western district. *C. Armstrongii*, its leaves stiff, sword-like and with a conspicuous orange midrib is the plant par excellence of the Westland side of the Southern Alps. *C. verbascifolia*, *C. holosericea* and *C. Petriei* are characteristic of the Fiord district, the latter has dagger-like leaves, green and glossy above, satiny-tomentose beneath and the margins much recurved. *C. lanceolata*, intermediate between *C. coriacea* and *C. Armstrongii*, is confined, so far as known to the mountains near Foveaux Strait.

The giant buttercups lighting up a hillside with their white or yellow blossoms are both of extreme physiognomic importance and beauty. *Ranunculus Lyallii* is the most striking and wide-spread occurring, as it does, from the Spenser Mts to Stewart Island; it is particularly plentiful in the Western district. The great glossy, green peltate leaves spreading horizontally, raised on stout stalks 30—45 cm high, cut off the light from the ground and forbid other plants to gain a footing, this being also assisted by the broad, half-buried, thick rhizomes paving the substratum. In the North-western district, *R. insignis* occupies a similar station, and in the Fiord district *R. Buchanani*

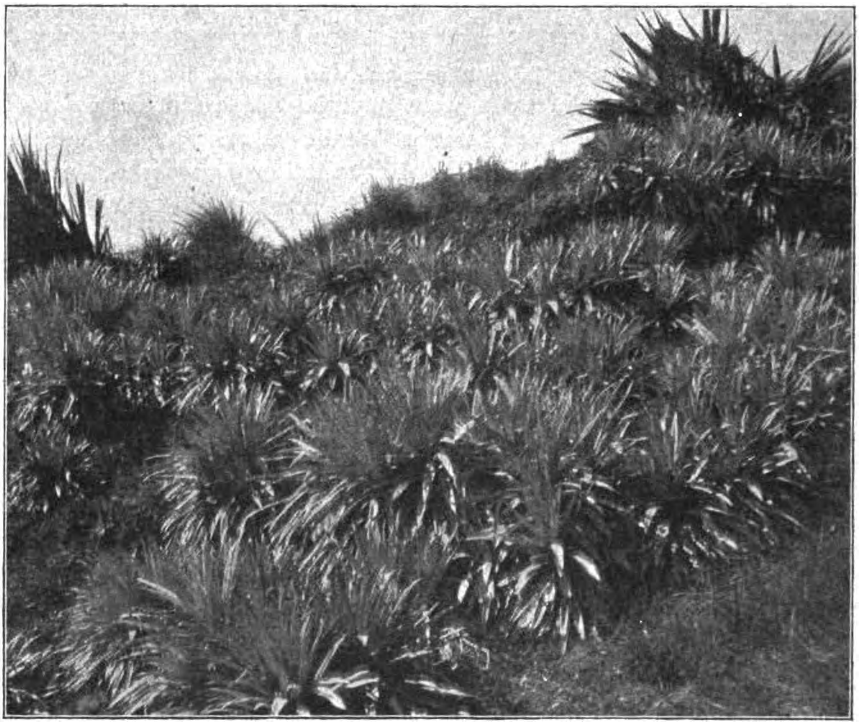

Fig. 81. *Celmisia coriacea* var. *stricta;* fell-field, Takitimu Mts., South Otago district. Photo L. Cockayne.

makes wide colonies, but usually only at a higher altitude and on more stony ground, a happening in accord with its more xerophytic structure.

Astelia montana and *A. Petriei* are common in many places. The latter with its shorter, more rigid, glossy leaf ascends to the alpine belt and completely fills snow- patch hollows.

The three large species of *Ourisia*, *O. macrocarpa* var. *calycina* (Western district), *O. macrophylla* (Northern part of South Island) and *O. macrocarpa* var. *cordata* (Fiord district) are in places as striking almost as the buttercups. The fern-like tufted leaves of *Anisotome Haastii* are a feature in herb-field generally. Various moderately tall species of *Aciphylla* are of moment at times especially — *A. crenulata* (Western district), *A. Hookeri*, *A. Townsoni* (North-western district), *A. Lyallii* Fiord district. The flat-cushioned species of *Celmisia* are of prime importance. *C. discolor*, *C. Sinclairii* and *C. sessiliflora* occur throughout. *C. dubia* (North-western district), *C. intermedia* (North-western district to the S. of the Western district), *C. Walkeri* (Western district southwards), *C. Hectori* (Fiord district) and *C. ramulosa* (Fiord and South Otago), this a true shrub. Species of *Gentiana* are conspicuous when in flower; *G. bellidifolia*, *G. Grisebachii* (probably annual), *G. patula* and *G. divisa* (local) occur throughout. *G. Townsoni* (North-western and Western districts), *G. montana* (North-western and Fiord districts) and some other species are of restricted distribution. Some of the smaller species of *Ourisia* are noticeable when in flower, e. g. — *O. caespitosa* (throughout), *O. Cockayniana* (Western and Fiord districts), *O. sessiliflora* (throughout), *O. prorepens* (Fiord) and *O. glandulosa* (Fiord and South Otago).

Certain subalpine shrubs invade the associations especially — *Phyllocladus alpinus*, several species of *Coprosma* and *Veronica subalpina*. Regular shrubby members are: — *Coprosma cuneata*, *C. ramulosa*, *C. retusa*, *C. serrulata* (spreading widely by means of underground stems), *Gaultheria depressa*, *G. rupestris*, *Pentachondra pumila* and *Carmichaelia grandiflora*. Important, but local are: — *Dracophyllum Menziesii* (Fiord district), *Veronica vernicosa* (North-western district to N. of Western district), *Coprosma depressa* (North-western district to N. of Western district) and *Senecio revolutus* (Fiord and S. Otago districts).

The general carpet of the association may be a striking feature, if the taller plants are scanty, or it may merely fill up the intermediate spaces. The following species are more or less common throughout: — *Hymenophyllum multifidum*, *Blechnum penna marina*, *Lycopodium fastigiatum*, *Hierochloe Fraseri*, *Agrostis Dyeri*, *Calamagrostis pilosa*, *Deschampsia Chapmani*, *Trisetum antarcticum*, *Danthonia semiannularis* agg., *Poa pusilla*, *P. caespitosa*, *P. Cockayniana*, *P. Colensoi*, *Festuca* sp., *Schoenus pauciflorus*, *Uncinia compacta*, *U. fusco-vaginata*, *Carex dissita* var. *monticola*, *Astelia linearis*, *Ranunculus foliosus*, *Caltha novae-zelandiae*, *Geum parviflorum*, *G. uniflorum*, *Acaena Sanguisorbae* vars., *Geranium microphyllum*, *Coriaria thymifolia*, *C. angustissima*, *Viola Cunninghamii*, *Epilobium chloraefolium*, *Aciphylla Monroi*, *Anisotome aromatica*, *Angelica decipiens*, *Euphrasia revoluta*, *E. zeylandica* and other species according to locality, *Plantago Brownii*, *Wahlenbergia albomarginata*, *Phyllachne Colensoi*, *P. clavigera*, *Forstera sedifolia*, *F. Bidwillii*, *Gnaphalium Traversii*, *Helichrysum bellidioides*, *Craspedia* spp., *Cotula pyrethrifolia*, *Senecio bellidioides*, *S. Lyallii* and *Taraxacum magellanicum*.

ε. Stewart Island.

As far as known, the only example of dry herb-field occurs on the sheltered side of the summit of Mount Anglem (970 m altitude). The cushion-plants of the wet herb-field, described below, are almost wanting. *Danthonia crassiuscula* and *D. pungens* dominate. *Ranunculus Lyallii*, *Celmisia Sinclairii*

Senecio Lyallii, *Astelia montana* and *Viola filiformis* are abundant. *Veronica Laingii* (cupressoid) is common and larger than in wet ground.

3. Wet Herb-Field.

This association is closely related to moor, but it varies considerably in its water-content and especially in the relation to drainage. Where, for example, the ground is subject to drainage by rapidly flowing streams the flora and growth-forms differ markedly from those of more strictly boggy ground. A distinction then may be drawn between badly-drained and semi-drained wet herb-field, the latter carrying a tall sub-mesophytic association and the former one that is low and xerophytic.

α. Semi-drained Wet Herb-Field.

The dominant species in the South Island are very frequently tussocks of *Schoenus pauciflorus* and rosettes of the summer-green *Senecio scorzoneroides*, the flower-heads of which, especially if white, render the association most conspicuous. *Ranunculus Lyallii* may be abundant. Green bushes of *Veronica buxifolia* may be dotted about, or form an actual scrub. A species of *Ourisia*, doubtfully referred to *O. Colensoi*, often forms wide patches. Other common plants are: — *Carex ternaria*, *Ranunculus foliosus*, *Viola Cunninghamii*, *Epilobium chloraefolium*, *Gentiana patula*, *Oreomyrrhis andicola*, *Celmisia petiolata*, *Helichrysum bellidioides*, spp. of *Craspedia*, *Microseris scapigera*, *Senecio Lyallii* and *Taraxacum magellanicum*.

The vegetation of banks of streams on the dry mountains is related to this formation. On such, the more mesophytic plants of the adjacent fell-field grow with much greater luxuriance. *Senecio Lyallii* and *Veronica buxifolia* var. *odora* are characteristic plants.

β. Badly-drained Wet Herb-Field (Herb-Moor).

This association might equally well be classed with moor from which it differs chiefly in the dryer ground, the absence of pools of water, *Sphagnum* and some other plants confined to actual bog, and the presence of plants which rarely or never extend on to boggy ground. As in moor, the abundance of cushions is a striking feature. The association attains its greatest development in Stewart Island, where it occupies all the mountains above the scrub-line and descends to within a few metres of sea-level at Port Pegasus in the S. of the Island.

Seen from a distance, the association, as it occurs in Stewart-Island, presents a most even and smooth surface, but when walking on it, one soon perceives it to consist of a dense mass of plants, springy to the tread, into which the feet sink but which rise back into their former position. There is a groundwork of the dominant species, others entering in according to changes in water-content, and perhaps becoming dominant. There are differences too in the association of the schist and granite mountains. The above groundwork consists of pale-green grass-like tufts of *Carpha alpina*, the leaf apices straw-coloured dead and twisted; close low cushions of *Donatia novae-zelandiae*, the green leaves with bright orange tips pressed together into small rosettes; *Dracophyllum politum* much like *Donatia* but the leaves more open and tipped with red; green cushions of *Oreobolus pectinatus* and growing through and mixed with the whole almost everywhere *Astelia linearis* and the small, flat, glaucous leaves of the grass *Microlaena Thomsoni.* Although the covering is made up of cushions, that form is masked through their growing into one another. At less than one metre apart, everywhere project obliquely above the general mass tufts of the rigid, sharp-pointed pale-green or reddish-brown leaves of the ungrass-like grass *Danthonia pungens.* On the schist mountains, where the soil becomes dryer, the general carpet is everywhere dotted with the silvery, dense cushions of *Celmisia argentea* (Plate LIII Fig. 82), and the more open and greenish tinged of *C. linearis.* Where the cushions of this latter unite, there are conspicuous silvery patches. Sometimes, for as far as the eye can see, there are the broad, shining green leaves in starry rosettes of *Senecio scorzoneroides* and, in December, its great white flower-heads. On the granite mountains, this latter and *C. linearis* are absent, *C. argentea* is rare, but there are sage-green circular mats of *C. Sinclairii*, *Chrysobactron Gibbsii* in abundance and *Veronica buxifolia* var. *prostrata.*

The following also occur more or less in the association: — *Lycopodium fastigiatum, Hierochloe Fraseri, Danthonia semiannularis, Prasophyllum Colensoi, Caltha novae-zelandiae, Anisotome aromatica, Pentachondra pumila, Suttonia nummularia, Gentiana lineata, G. Grisebachii, Euphrasia Dyeri, Phyllachne Colensoi, Forstera sedifolia* var. *oculata, Celmisia longifolia, Raoulia Goyeni* (at times) and *Senecio bellidioides.*

On the mountains of the South Island generally, there does not seem to be ever so dense a turf composed of cushion-plants, as described above [1]), though all, except the endemic members of the association, are found at some locality or other.

The dwarf taxad, *Dacrydium laxifolium*, is frequently a dominant plant and makes a compact and continuous turf. Lax cushions, 2 m or more in diam., of the shrub *D. Bidwillii* are characteristic. There may be extensive colonies of the fern *Gleichenia alpina* or of the wiry-stemmed *Hypolaena lateriflora.* Patches of *Astelia montana* or *Astelia Petriei*, and the much smaller *A. linearis* are certain to be present. Probably there will be tussocks of *Danthonia Raoulii* and *Schoenus pauciflorus.* Circular mats of species of *Cel-*

1) Perhaps nearest in ecological character to the association described above is that of the flat summit of the Old Man Range (South Otago) extending for some miles. Here the ground consists of peaty hummocks on which grow the following: *Hierochloe Fraseri, Agrostis subulata, Poa Colensoi, Ranunculus novae-zealandiae, Drapetes Lyallii, Anisotome aromatica* var *lanuginosa, Dracophyllum muscoides, Veronica Hectori, V. dasyphylla, Phyllachne Colensoi, Ph. rubra, Celmisia argentea, C. brevifolia, C. viscosa, Craspedia* spp., *Raoulia grandiflora, R. Hectori* and *Senecio bellidioides* (glabrous var.).

misia, especially *C. intermedia*, will be dotted about. Different species of *Gentiana*, according to the locality, may be abundant. Many of the following are frequent plants of the association: — *Hierochloe Fraseri*, *Calamagrostis setifolia*, *Oreobolus pectinatus*, *Carpha alpina*, prostrate *Leptospermum scoparium*, *Aciphylla crenulata* (Western district), *A. Townsoni* (North-western district), *Gaultheria depressa*, *G. perplexa*, *Styphelia empetrifolia*, *Pentachondra pumila*, *Gentiana bellidifolia*, *G. patula*, *G. Townsoni* (North-western and N. of Western districts), *G. lineata* (Southland), *Forstera sedifolia*, *Donatia novae-zelandiae*, *Celmisa glandulosa* (an abundant and characteristic plant), *Senecio scorzoneroides* and *S. Lyallii*.

6. Aquatic Associations.

Here are comprised associations of running and still water including those of flushes, but excluding those of dripping rocks. The aquatic plants of the high mountains number only 11 belonging to 8 families and genera.

Where streams flow swiftly *Algae* and perhaps a moss or two are present, their presence on stones marking the normal depth of the water[1]). The chief ecological difference between mountain and lowland streams is the much lower temperature of the former in many cases. The most characteristic species is *Montia fontana* which may fill small brooks, even floating upon the surface, or form close cushions in shallow fairly rapid streams (Plate LIV, Fig. 83). *Epilobium macropus* is common both in shallow parts of rather slow-flowing brooks and in shallow water on river-beds, a station also of *Claytonia australasica*. *Carex Buchanani* occurs abundantly in the South Island at the margin of streams. In fairly rapid brooks, there is often a dense growth of *Myriophyllum propinquum*, the leaves submerged and pointing down the stream. On the Volcanic Plateau and in many parts of the South Island, *Gunnera dentata* forms close masses in very shallow water and on the wet ground adjacent, its leaves flattened to the soil excluding other plants. In many South Island shallow streams, the water with, or without excess of lime, there is a close growth of the slender-stemmed *Schizeilema nitens* distinguished by its small shining, trifoliate, thin, glabrous leaves. *Ranunculus Cheesemanii* is typical of shallow montane streams in the North-eastern botanical district, and *R. rivularis* is common in most localities throughout.

Water gushing out of the ground in varying abundance and usually keeping the soil icy-cold is a common feature of the high-mountain area and the following species especially, each according to its range, affects the habitat: *Poa dipsacea*, *Carex Gaudichaudiana*, *C. Petriei*, *Scirpus aucklandicus*, *Eleocharis Cunninghamii*, *Juncus novae-zelandiae*, *Chrysobactron Hookeri*, *Claytonia australasica*, *Ranunculus Sinclairii*, *R. depressus*, *Cardamine heterophylla*, *Drosera spathulata*, *D. arcturi*, *Acaena saccaticupula*, *Geranium microphyllum*, *Oxalis magellanica*, *Viola Cunninghamii*, *Epilobium pedunculare* agg., *E. ner-*

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1) In winter many glacial streams even of considerable size become quite dry and during the rest of the year the amount of water of most mountain rivers and streams varies greatly.

terioides, *E. macropus*, *Hydrocotyle novae-zelandiae*, *Schizeilema nitens*, *Isotoma fluviatilis*, *Pratia angulata*, *Mazus radicans*, *Ourisia Crosbyi*, *Plantago triandra*, *P. uniflora*, *P. Brownii*, *P. lanigera*, *Gnaphalium paludosum*, *G. Traversii* var. *Mackayi*, *Helichrysum bellidioides*, *Cotula squalida*, *Abrotanella linearis* and *Craspedia uniflora*.

The associations of lakes differ but little from those of the lowland belt. The same species of *Potamogeton* and *Myriophyllum* are present and the swamp species of the margin[1]) are all lowland forms. *Isoetes alpinus* and *Pilularia novae-zealandiae*, submerged aquatics, are probably common.

7. Swamp.

Swamp occurs principally in the montane valleys of the South Island and owes its origin to frequent flooding of the ground by rivers and streams, especially during rapid melting of snow; where the drainage is insufficient, it is readily transformed into moor. There is little of an alpine character about the formation; *Carex virgata* or *C. secta* are frequently dominant and *C. ternaria*, *C. stellulata* and *C. diandra* are extremely common.

8. Moor.

There is little to separate badly-drained herb-field[2]) from moor, the chief distinctions being a more boggy soil and the presence usually of more or less *Sphagnum* and shallow water-holes.

The number of species for the whole formation is 110, belonging to 32 families and 65 genera, and made up of the following growth-forms: — Trees (much-stunted) 3; shrubs 19; herbs 67; grass-like plants 13; rush-like 5 and ferns 3. Cushion-plants number 11. The following are some of the most important and wide-spread species: — *Gleichenia alpina*, *Dacrydium laxifolium*, *Danthonia Raoulii*, *Scirpus aucklandicus*, *Carpha alpina*, *Schoenus pauciflorus*, *Oreobolus pectinatus*, *Carex Gaudichaudiana*, *Hypolaena lateriflora*, *Gaimardia ciliata*, *Astelia linearis*, *Herpolirion novae-zelandiae*, *Drosera arcturi*, *D. spathulata*, *Geranium microphyllum*, *Viola Cunninghamii*, *Leptospermum scoparium*, *Halorrhagis micrantha*, *Gaultheria depressa*, *Pentachondra pumila*, *Styphelia empetrifolia*, *Veronica buxifolia*, *Utricularia monanthos*, *Phyllachne Colensoi*, *Celmisia glandulosa* and *Gnaphalium paludosum*.

As in herb-field, so here, the degree of drainage is reflected in the associations.

a) *Schoenus-pauciflorus moor.*

This is a most conspicuous association of the South Island steppe area, as also to some extent on the Volcanic Plateau. *S. pauciflorus* is dominant, the reddish-colour of its tussocks marking it off, at a considerable distance

1) *Typha angustifolia* var. *Muelleri* ascends to about 750 m, on an average, in the South Island; *Eleocharis Cunninghamii*, *Cladium glomeratum*, *Carex subdola*, *C. secta* and *C. pseudocyperus* are the accompanying plants of shallower water.

2) Indeed I am calling such "Herb-moor".

from the brown tussock-steppe of the South Island. Although the moor is traversed by running streams, the ground is sopping wet. *Sphagnum*-cushions are usually plentiful and growing on them certain small herbs, e. g. — *Blechnum penna marina*, species of *Drosera*, *Geranium microphyllum*, *Viola Cunninghamii*, *Halorrhagis micrantha*, *Nertera Balfouriana* and *Celmisia longifolia* var. *alpina*. *Chrysobactron Hookeri* var. *angustifolia* is usually abundant.

Closely related to the above in the North-eastern and Eastern districts are associations where *Schoenus* is not dominant, *Sphagnum* abundant and shrubs present e. g. — *Leptospermum scoparium*, *Gaultheria depressa*, *G. rupestris*, *Dracophyllum uniflorum*, *Veronica buxifolia* and *Cassinia Vauvilliersii*. *Astelia montana* is frequently an important feature. In many places, *Carex Gaudichaudiana* will dominate.

b) Badly-drained moor.

1. Cushion-moor.

The ground will be extremely wet peat and quake under the feet; there will be pools of water and floating *Sphagnum*. The greatest development of the association is on wet South Island mountains and the boggy areas are usually quite small. The special feature is the numerous, small, dense cushions of the following, some of which may be absent: — *Oreobolus pectinatus*, *O. strictus*, *Gaimardia ciliata*, *G. setacea*, *Phyllachne clavigera*, *P. Colensoi* and *Donatia novae-zelandiae*. In addition most of the following will be present: — *Gleichenia alpina*, *Dacrydium laxifolium*, bushes of *D. Bidwillii*, *Carex Berggreni* (South Otago), *Carpha alpina*, *Hypolaena lateriflora*, *Astelia linearis*, species of *Drosera*, prostrate *Leptospermum scoparium*, *Plantago triandra*, *Pentachondra pumila*, *Styphelia empetrifolia*, *S. pumila*, one or more species of *Gentiana*, *Celmisia longifolia* var. *alpina* and *C. glandulosa*.

2. Hypolaena-Gleichenia Moor.

This association closely resembles that of the lowlands; many of the species already mentioned will be present.

Moor of this character occurs on the Volcanic Plateau, but its presence depends upon abundant ground-water supplied by melting of the winter snow since the drainage is good. *Gleichenia alpina* is plentiful but the grass-like *Carpha alpina* with its pale-green leaves, withered and twisted at their extremities, is the special feature. There is abundance also of *Oreobolus pectinatus*, *Viola Cunninghamii* and *Celmisia glandulosa*. In the same district where the conditions are truly boggy the dark-green *Liparophyllum Gunnii* forms close mats together with a turf of *Carpha alpina*, *Scirpus crassiusculus*, *S. aucklandicus* and *Gnaphalium paludosum*. *Utricularia monanthos* is extremely plentiful. Other common plants are: — *Danthonia Raoulii*, *Juncus antarcticus*, *Carex ternaria*, *Aciphylla squarrosa*, *Gentiana bellidifolia*, *Coprosma* *repens* and *Craspedia minor*. Better drained, though constantly wet ground, brings *Hypolaena* and *Gleichenia* into dominance accompanied by abundance of *Veronica buxifolia*, and many of the shrub-steppe shrubs much dwarfed are raised on dryer mounds above the general level.

Section IV.

The Vegetation of the Outlying Islands.

Chapter I. The Vegetation of the Kermadec Islands.

1. General.

The species of pteridophytes and spermophytes of the Kermadec Island number respectively 38 and 77 and belong to 42 families and 88 genera. Floristically the largest families and the number of species in each are, — *Filices* 27; *Gramineae* 12; *Compositae* 9; *Cyperaceae* 6 and *Convolvulaceae* 4. The elements of the florula are as follows: — Endemic 12 species; New Zealand 89 of which 15 are endemic, 66 Australian and 6 of the remaining 8 occur in Lord Howe and Norfolk Islands taken together; Norfolk Island 55; Lord Howe Island 44; Polynesian 54 and Australian 74. There are thus only 8 Australian species which do not occur in New Zealand but, on the other hand, of the 66 Australian-New Zealand species, 49 occur also in Norfolk or Lord Howe Islands one or both and 17, 6 of which also are Polynesian, occur in New Zealand and the Kermadec Islands. Without going more deeply into the matter, the above figures show how closely related is the Kermadec florula to that of Lord Howe and Norfolk Islands[1]). The New Zealand-Kermadec species are by no means solely plants of the N. of New Zealand since 68 occur in the Northern, Central and Southern provinces, or, deducting 9 which only just enter the last-named province, 51 p. c. of the New Zealand element are of wide-spread distribution. As for the remainder, 7 are confined to the Northern and 13 to this latter and the Central province, but 8 of these are virtually Northern so that 17 p. c. must be so considered and 1 to the Central province. As for the outlying provinces 43 species (40 p. c.) occur in the Chatham and 7 (all pteridophytes) in the Subantarctic province[2]). One interesting fact of distribution is the occurrence of two most closely related species of *Coprosma* in the Kermadec and Chatham provinces, *C. petiolata* in the former and *C. chathamica* in the latter both of which are absent

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1) 36 species are common to Norfolk, Lord Howe and the Kermadec Islands, but only 2 of these are not also Australian.

2) The absence of the genera *Uncinia*, *Acaena* and *Epilobium*, so easily carried by birds or wind, is quite as remarkable as the facts of actual distribution.

elsewhere but closely related to the New Zealand-Kermadec-Norfolk-Howe *C. Baueri*[1]).

The general ecological conditions of the Kermadecs are a combination of a moist humid climate, coastal conditions and an extremely porous soil. According to OLIVER, (1910 : 125), calm days are rare and the wind often blows with great violence. The rainfall is fairly evenly distributed throughout the year. In cloudy and rainy weather a mist continually hangs about the hilltops and its influence is reflected by a distinct forest-association.

2. The leading Physiognomic Plants.

The following are the leading physiognomic plants of the Kermadec vegetation, all of which are either identical with, or closely related to mainland species: — *Metrosideros villosa* (Myrtac.), *Rhopalostylis Cheesemanii*[2]) (Palmae), *Rapanea kermadecensis* (Myrsinac.), *Ascarina lanceolata* (Chloranthac.), *Myoporum laetum* (Myoporac.), *Corynocarpus laevigata* (Corynocarp.), *Melicytus ramiflorus* (Violac.), *Coprosma petiolata* (Rubiac.), *Macropiper excelsum* var. *major* (Piperac.), the endemic tree-ferns (*Cyathea Milnei*, *C. kermadecensis*) and a number of herbaceous ferns, especially, — *Pteris comans*, *Polystichum aristatum*, *Nephrolepis exaltata*, *Dryopteris glabella* and *Blechnum norfolkianum*. Only a few of the above need a brief notice.

Metrosideros villosa, also found in Lord Howe Island, New Caledonia and Polynesia, is either a lofty tree 20 m high or its massive trunk is more or less prostrate. In the latter case, trunk-like branches pass upwards from the prostrate trunk. Aereal roots are extremely abundant in both forms; in the erect tree they grow downwards, pass into the soil and function as stems; in the prostrate form they make entangled masses at the base of the trunk. The leaves are similar to those of *M. tomentosa* but smaller.

Rhopalostylis Cheesemanii closely resembles *R. sapida* but is taller. *Rapanea kermadecensis* is a low tree, 6—10 m high with smooth reddish-gray bark and dense foliage of elliptic-oblong, dark-green, coriaceous leaves and with the small flowers produced, in part, on the naked twigs; its fruit is fleshy. *Ascarina lanceolata* is a tall shrub or low tree much resembling *A. lucida*, already described. *Coprosma petiolata* is very similar to *C. chathamica*; it varies from a quite prostrate shrub to a low tree 6 m high. *Cyathea Milnei* has a stout trunk 2—8 m high, clothed above with persistent withered leaves while *C. kermadecensis* is a magnificent plant, 15—20 m high with a naked trunk 1—2 m in diam. at the base which consists chiefly of aereal roots.

3. Biology of the Plants.

a. Trees and shrubs.

These number 21 of which 5 are of medium height (maximum 20 m); 12 low and 4 shrubs. The growth-forms and number of species to each are

1) But see, further on, W. R. B. OLIVER's opinion regarding the *Coprosma Baueri* group.

2) This is endemic and it raises that element to 13.

as follows: — Canopy tree 4; tuft-tree 3 (palm 1, fern 2); bushy-tree 10; bushy-shrub 2; straggling-shrub 1. Most of the trees also occur as shrubs. Three species which in New Zealand proper are rarely more than low trees here attain a stature of 20 m.

The leaves of the trees and shrubs are: — compound 5; simple 16; very large (more than 20 cm long) 5; large (10—20 cm) 2; medium (5—10 cm) 10; small (2.5—5 cm) 4; coriaceous or thick 8; thin 13; glabrous 18; hairy 3 (tomentose 2); rolled 3; glossy 6; waxy beneath 1.

Aereal roots are abundant in *Metrosideros villosa* and are in harmony with a moist atmosphere. In wet forest, states OLIVER, "the prostrate trunk of a tree may be a metre above ground supported by hundreds of large and small root-props, and sending up large branches like distinct trees".

b. Herbs, semi-woody plants, lianes and epiphytes.

The herbs and semi-woody plants number 77 of which 10 are annuals or biennials, 4 summergreen, 5 semi-woody and perhaps 7 xerophytes or sub-xerophytes. Regarding height, 3 are very tall (more than 90 cm), 22 tall (60—90 cm), 13 of medium height (30—60 cm), 29 small (15—30 cm), and 10 very small (less than 15 cm).

The growth forms together with the number of species to each are as follows: — 1. Annuals or biennials 10 including: — erect-branching herb 7; tuft-grass 2 and semi-prostrate grass 1. 2. Perennials 67 — *α*. Spot bound 45, — *a*. semiwoody 3 including, — erect-branching 2 and mat 1. — *b*. herbaceous 42 including, — tufted-form 19 (fern 11, grass 7, rush 1); tussock-form 6 (grass 3, rush 3); erect-branching 8; straggling 5 and erect non-branching 4 (all summergreen). — *β*) Wandering 22 — *a*. semi-woody 2 including, — erect-creeping 1; mat-form 1 — *b*. herbaceous 20 including, — erect-creeping 14 (fern 10, herb 4); turf-form 1 and mat-form 5.

Lianes number 5; all, except *Lycopodium volubile*, are coastal herbs; their biology has been already dealt with when treating of the mainland vegetation.

There are 12 epiphytes (ferns 10, including filmy 4, creeping 3, tufted 2; lycopods 2; and succulent creeping herb 1). It is worthy of note that the monocotylous and dicotylous lianes and epiphytes of the mainland are unrepresented.

The leaves of the 94 plants here being dealt with may be characterized as follows: — very large (over 20 cm long) 8; large (10—20 cm) 21; medium 5—10 cm 19; small (2.5—5 cm) 33; very small (2.5 cm or less) 9; thin 57; thick or coriaceous 33; glabrous 83; hairy 7. Four species are leafless.

4. The Plant-Formations[1].

a. Coastal Formations.

1. Rock.

Nearly all the coast-line is rocky. The rock-association is uniform throughout and related to that of the Northern botanical province. The most impor-

1) What follows is based on W. R. B. OLIVER 1910: 118—175.

tant members are: — *Asplenium obtusatum*, *Poa polyphylla* (endemic), *Mariscus ustulatus*, *Scirpus nodosus*, *Parietaria debilis*, *Mesembryanthemum australe*, *Tetragonia expansa*, *Apium prostratum*, *Samolus repens* var *strictus*, *Lobelia anceps* and *Coprosma petiolata* (endemic and ecologically equivalent to *C. Baueri*).

2. Talus slopes.

These, at the base of sea-cliffs are characterized by close-growing tussocks of *Mariscus ustulatus* together with the ferns *Pteris comans* and *Hypolepis tenuifolia*, tussocks of *Scirpus nodosus* and *Carex semi-Forsteri* and shrubby *Myoporum laetum*.

3. Scrub.

Scrub forms a belt, where there is sufficient space, between the foot of the cliffs and high-water mark; it also constitutes most of the vegetation of Meyer Island. Shrubby *Myoporum laetum* is dominant. Other members of the association are: — *Pteris comans*, *Mariscus*, *Carex pseudo-Forsteri*, *Macropiper excelsum* var. *major*, *Canavalia obtusifolia* and *Sicyos australis* (tendril liane).

4. Dune.

Dune is extremely limited in area. *Ipomaea pes caprae* is easily dominant and extends to some metres on to the beach other species are: — *Imperata Cheesemanii* (endemic), *Scirpus nodosus* and *Apium*.

5. Gravel flat.

In Denham Bay a gravel flat extends for 2 km with an average width of 74 m. It is subject to frequent drenching by sea-spray. The leading species are: — *Ipomaea pes caprae* (dominant), *Imperata Cheesemanii*, *Calamagrostis Forsteri*, *Mariscus ustulatus* (sub-dominant), *Scirpus nodosus* (abundant), *Tetragonia expansa*, *Myoporum laetum*, *Calystegia Soldanella*, *Scaevola gracilis* and *Erechtites prenanthoides*.

b. Inland formations.

1. Rock.

The following are important rock-plants: — *Cyclophorus serpens*, *Asplenium Shuttleworthianum*, *Psilotum triquetrum*, *Carex semi-Forsteri*, *Peperomia Endlicheri*, *Mesembryanthemum australe*, *Hydrocotyle moschata*, *Veronica breviracemosa* (endemic), *Scaevola gracilis* and *Lagenophora petiolata*.

2. Warm ground near steam-vent.

Although where the steam strikes directly there are no plants, at a short distance away is a close growth of: — *Nephrolepis exaltata*, *Polypodium diversifolium*, *Lycopodium cernuum*, *Psilotum triquetrum* and *Paspalum scrobiculatum*.

3. Swamp.

There are a few small swamps. *Typha angustifolia* var. *Brownii* is dominant. Other species are: — *Blechnum capense*, *Histiopteris incisa* and

Juncus polyanthemos; where the water is shallow near margin of the Green Lake there is a belt of *Typha*.

4. Forest.

Virtually the whole of Sunday Island is forest-clad, — a distinct expression of climate. The forest may be divided into the two classes, *wet* and *dry*.

Wet forest is composed of a mixture of trees none of which is dominant. The principal trees are: — *Ascarina lanceolata*, *Melicytus ramiflorus*, *Nothopanax arboreum*, *Rapanea kermadecensis* and *Coprosma acutifolia*. *Metrosideros villosa*, of huge dimensions, occurs in places. Frequently one species or another makes a pure stand. *Rhopalostylis Cheesemanii* and *Cyathea kermadecensis* are generally extremely plentiful. The abundance of epiphytic ferns is a striking feature.

Dry forest is characterised by the dominance of *Metrosideros villosa*. The average height is some 20 m; there are 3 tiers of vegetation. Different combinations form the lowermost tier in different localities, e. g.: — *Polystichum aristatum* 1—2 m high may make an impenetrable mass, or *Nephrolepis cordifolia* occupy wide areas, its matted roots spreading over the ground or fallen logs or climbing the tree-fern trunks, or again the underground be merely a dense mass of the stems of *Macropiper*. The second tier may consist of small trees, the palm and tree-ferns, the first-named being especially — *Melicope ternata*, *Boehmeria dealbata*, *Coriaria ruscifolia*, *Corynocarpus laevigata*, *Melicytus ramiflorus*, *Rapanea kermadecensis*, *Myoporum laetum* and *Coprosma acutifolia*. In places the palm forms pure stands (see Plate LV, Fig. 84). The third tier consists of the *Metrosideros* together with *Corynocarpus* and *Myoporum* which almost equal it in stature. The forest-roof is fairly dense.

Chapter II. The Vegetation of the Chatham Islands.

1. General.

The florula of the Chatham Islands consists of 239 species which belong to 56 families and 141 genera. The families and genera most important floristically together with the number of species in each are: — *Filices* 50; *Compositae* 23; *Cyperaceae* 20; *Gramineae* 13; *Orchidaceae* 12; *Onagraceae* 10; *Umbelliferae* 9; *Epilobium* 10; *Hymenophyllum* 8, *Blechnum* and *Scirpus* 6; *Lycopodium*, *Coprosma* and *Veronica* 5. The florula consists of 32 endemic species; 205 New Zealand of which 105 are Australian, 25 Australian-South American, 5 South American, 9 Cosmopolitan and 6 Polynesia or Norfolk Island etc.; 1 Australian[1]) and 1 South America[2]). With regard to the distribution of the New Zealand element on the mainland no fewer than 180 species (87 p. c.) occur in all 3 botanical provinces while 6 occur only in the Northern,

1) *Myriophyllum pedunculatum.*
2) *Carex Darwinii* var. *urolepis.*

4 in the Northern and Central, 11 in the Central and Southern and 4 in the Southern. Of the above mainland plants 42 belong also to the Subantarctic province and 22 to the Kermadec. The endemic element is remarkable as containing 20 species[1]) (62 p. c.) closely related to one or more of those of the mainland, so that, at first glance many can hardly be distinguished. On the other hand, the endemic genera *Coxella* and *Myosotidium*, as also the endemic *Festuca* and *Geranium* together with *Olearia Traversii*, *Cotula Featherstonii* and its ally *C. Renwickii* stand out distinct from other New Zealand plants and represent either species of an earlier flora or such as were once found on the mainland.

The ecological conditions of the Chatham Islands consist of a combination of coastal, rain-forest and subantarctic factors. Thus, at no part of the main island are you distant 7 km from the sea and the extreme is, in most places less than one half of this. High winds are frequent, especially those from the N.W. and S.W. The rainfall is not great, but the number of wet days is excessive, while cloudy skies are frequent. Frost is trivial and snow falls but rarely. The soil in many parts consists of peat frequently more than 6 m in depth and always in a complete state of saturation. There is however, in certain localities, a much more fertile soil known locally as "red clay", the outcome from weathering of the volcanic rock. The main features of the vegetation, as will be seen further on, clearly reflect the climatic and edaphic conditions.

2. The leading Physiognomic Plants and their Growth-forms.

Certain physiognomic plants common on the main islands of New Zealand need no further description here, e. g. — the various tree-ferns, *Pteridium esculentum*, *Scirpus frondosus*, *Rhopalostylis sapida*, *Leptocarpus simplex*, *Rhipogonum scandens*, *Phormium tenax*, *Macropiper excelsum*, *Muehlenbeckia australis*, *Mesembryanthemum australe* and *Corynocarpus laevigata*. Other species again have growth-forms identical with those of their mainland relatives and differ merely in taxonomic characters, e. g. — *Carex appressa* var. *sectoides*, *Pseudopanax chathamicum*, *Styphelia robusta*, the one species of *Dracophyllum*, the large-headed species of *Olearia* and *Cotula potentillina*. There remain then only the following species, all endemic except the first, to be considered: — *Suttonia chathamica*, *Myosotidium nobile*, *Veronica gigantea*, *Coprosma chathamica*, *Olearia Traversii* and *Senecio Huntii*.

Suttonia chathamica (F. Muell.) Mez (Myrsin.) varies from a dense shrub 1—2 m high to a round-headed low tree 4—8 m high with the trunk 30—60 cm in diam. and covered with dark bark. The leaves vary in size according to the degree of exposure, but in the forest they are obovate, about 5.5 cm × 3 cm, dull-green, rather thick, coriaceous and crowded at the ends of the twigs.

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[1]) I am including *Suttonia Coxii*, for *S. chathamica* to which it is related occurs in Stewart Island. On the other hand, I am not counting *Adiantum affine* var. *chathamicum*.

The flowers are very small, hermophrodite, and arranged in fascicles upon the naked twigs. The fruit is purplish, globose and somewhat fleshy. The species has been also noted in two localities in Stewart Island.

Myosotidium nobile Hook. (Borrag.), the Chatham Island lily, has a stout root-stock 5 cm in diam. which creeps just below the ground-surface, or is partly unburied. The rhubarb-like leaves are in erect rosettes; they are ovate-cordate to reniform, 25 cm long $\times$ 30 cm broad, more or less, and consist of a comparatively thin blade strengthened beneath by a stout framework of midrib and veins; the leaf-stalks are stout and about 12 cm long. The flowers, each about 1.2 cm in diam., the central half of the corolla bright blue and the outer half white, are arranged in dense, sub-globose, many-flowered cymes borne on stout stalks 60 cm high. The genus is endemic and monotypic.

Veronica gigantea Cockayne (Scroph.) is a low forest-tree 4.5—9 m high with an erect trunk 30 cm or more in diam. and a close, rounded crown. The leaves are lanceolate, 7—9 cm long, soft, dull-green and moderately thick. Though like a gigantic form of *V. salicifolia*, the seedling-form is altogether distinct in its early leaves deeply and coarsely toothed, their margins ciliated, with hooked, white hairs and the strongly pubescent soft, purple stem. Succeeding leaves are larger than the adult; and, although entire are still ciliated and also pubescent on the midrib. Plants more than 60 cm high maintain the juvenile character.

Coprosma chathamica Cockayne (Rubiac.) is a tree 4.5—15 m high with a trunk 30—60 cm in diam. covered with light-brown bark and having oblong, obovate-oblong or lanceolate leaves about 4.9 cm long, dark-green, somewhat thin, shining above but pale beneath, flat or with the margins more or less incurved. The species is closely related to the Kermadec *C. petiolata*, to which it was referred by HOOKER and it is near to *C. Baueri*.

Olearia Traversii (F. Muell.) Hook. f. (Compos.), the Chatham Akeake, is a small tree 4.5—9 m high with a trunk 30—60 cm in diam. covered with pale, rough bark and a rather dense crown. The leaves are opposite, oblong to ovate, 5.5 cm long or shorter, soft, rather thick, bright shining-green above and beneath clothed with dense, silky tomentum, as are also the branchlets, inflorescence-branches and involucres. The numerous, small flower-heads are in much-branched, axillary panicles, 5—7.5 cm long.

Senecio Huntii F. Muell. (Compos.), the Rautini, is a small tree 3—6 m high of the tree-composite type, with a trunk 30 cm, or so, in diam. and 20—24 leaves in rosettes at the ends of the branchlets. The leaves are lanceolate, sessile, about 12 cm $\times$ 3.5 cm, pale but shining green above and greyish-green beneath with short, glandular hairs. The flower-heads, each some 1.3 cm in diam., with 15—20 yellow ray-florets, are in massive much-branched, terminal panicles, 10 cm or more in breadth. Flower-stalks, involucres, branchlets etc. are densely covered with glandular hairs which fill the air with a powerful aromatic scent. Seen from a distance, the foliage forms a bluish semi-spherical mass, but when in full blossom, fully one half is concealed by the brilliant yellow.

3. The Biology of the Plants.

a. Trees.

Trees number 21; their growth-forms are: — Tuft-tree 6 (palm 1, ferns 5); canopy-tree 7; bushy-tree 6; tree-composite 1; araliad 1. All are usually low but at times a few may reach a stature of 15 m or more but as a rule they vary from 6—13 m according to situation. Several readily assume the shrub-form especially *Suttonia chathamica* and *Olearia Traversii. Dracophyllum arboreum* is not of the usual fastigiate habit of its congeners and is here included amongst the canopy-trees.

Generally, the tree-crowns are denser than those of the same species of the mainland and resemble those of coastal trees. The trunks are slender and straight. The appearance of *Veronica* and *Coprosma*, as true forest-trees, must be specially noted. *In species or genera strongly heteromorphic in New Zealand proper the phenomenon is exhibited to a very trifling extent,* e. g. — the juvenile forms of *Plagianthus betulinus* and *Sophora* just hint at the divaricating form. So too with *Pseudopanax chathamicum*, the juvenile stage has leaves of an adult type, but it nevertheless persists for sometime with straight unbranched stem. *Dracophyllum arboreum* has broad spreading leaves as juvenile after the manner of but not nearly so broad or large as *D. latifolium* but absolutely distinct from the narrow grass-like leaves of the adult. They appear on reversion-shoots in the crown of the tree and this stage may blossom. The juvenile *Coprosma chathamica* has much more mesophytic leaves than the adult and they are frequently much larger. The heterophylly etc. of *V. gigantea* has been already described.

Coming now to the leaves; those of 20 are broad (simple 13, compound 7) and of 1 grass-like; 19 have glabrous leaves, 2 hairy (1 tomentose); 12 thin and 9 coriaceous or thick. Their dimensions are: very large (20 cm and upwards in length) 6; large (10—20 cm long) 3; medium (5—10 cm) 4; small (2.5—5 cm) 8. All are evergreen excepting *P. betulinus* var. *chathamicus* and perhaps the *Sophora*.

The flowers of 5 species are more or less showy, 9 have succulent fruits and those of 2 specially suitable for wind-carriage.

b. Shrubs lianes and epiphytes.

Shrubs number 21 including the bamboo like *Sporodanthus Traversii*; the remainder belong to the following growth-forms: — Bushy-shrub 9; divaricating 4 (1 spinous); composite-shrub 2; semi-ball-like 1: straggling 2; *Dracophyllum*-form 1, prostrate 1. So far as individuals go the shrub-composite and *Dracophyllum*-forms are of prime physiognomic importance and specially reflect the prevailing climatic-edaphic conditions.

All the species have simple leaves; their characteristics and the number of species possessing such are as follows: — Medium-sized 8; small 4; very small (less than 2.5 cm long) 8; thin 5; coriaceous or thick 16; glabrous 15; hairy 4 (tomentose 3). *Sporodanthus* is leafless.

Olearia semidentata varies to an astonishing degree in the form of its leaves and the amount of tomentum, so much so that plants growing side by side, so far as general appearance goes, might be taken for distinct species. The roots, which are of considerable length, project laterally and not vertically downwards. The flower-heads have most brilliant purple ray-florets.

Dracophyllum paludosum has a long, creeping, slender, subterranean stem which gives off numerous cord-like roots, an organ already developed while a seedling. Both the above species frequently flower when only a few centimetres high.

Lianes are only represented by the 6 common New Zealand species, — *Lycopodium volubile*, *Rhipogonum scandens*, *Muehlenbeckia australis*, *Tetragonia trigyna* and *Calystegia tuguriorum*, all of which have been dealt with for lowland New Zealand.

Epiphytes number 14; all but one are mainland species and consist merely of 2 orchids, 4 filmy ferns, 7 thick- or coriaceous-leaved ferns and *Tmesipteris*. The exception, *Dracophyllum arboreum*, an endemic tree, commences its career as an epiphyte on the trunk of a tree-fern, the roots passing downwards, and eventually entering the ground, coalesce and form a trunk, thus behaving in a similar manner to *Nothopanax arboreum* and several other trees.

c. Herbs, semi-woody plants and aquatics.

The total number of species of herbs and semi-woody plants is 174 of which 12 are annuals, 162 perennials, 28 semi-woody, 146 herbs, 78 wandering and 96 spot-bound. Regarding their stature 7 are very tall (more than 90 cm tall); 17 tall (from 60—90 cm); 41 of medium height (30—60 cm); 52 small (15—30 cm); 53 very small (less than 15 cm) while 4 hug the ground or are at most 3 cm tall.

The growth forms of the species are as follows together with the number of species to each: — 1) Annuals 12 of which 10 are erect branching herbs, 1 tufted-grass and 1 tufted-rush. 2) Semi-woody plants 28, — a) Spot-bound 18, made up of, — erect-branching 8; erect unbranching 1; straggling 7; tufted-fern 1; rosette-form 1; b) Wandering 10 made up of, — rooting mat-form 8; erect-branching 1; erect creeping and rooting 1. 3) Herbs 134, — a) Wandering 67 made up of, — erect-creeping 28 (ferns 15, grass-form 4, rush-form 5, herb-form 4); mat-form 29 (filmy ferns 6, rush-form 4, herb-form 19); *Iris*-form 1; orchid-form 2; rosette-herb 3; herb-turf 3, *Utricularia*-form 1. b) Spot-bound 67 made up of, — tufted-form 23 (ferns 9, tufted-grass 11, tufted-rush 3); tussock 10 (grass 7, rush 3); erect un-branching 2; straggling 5; straggling mat 2; erect-branching herbs 7; rosette-form 6; orchid-form 8; *Yucca*-form 2 and *Iris*-form 2.

Coming now to the leaves, 9 species have very large leaves (over 20 cm long); 20 large (10—20 cm); 25 of medium size (5—10 cm); 78 small (2.5—5 cm), 33 very small (2.5 cm or less); 109 thin; 57 thick, coriaceous or succulent; 138 glabrous and 27 hairy (tomentose 5). Nine species are leafless.

The 3 water-plants are similar to the same species of the mainland and need no further description.

d. Seasonal changes.

Only a brief note can be given as to seasonal changes. *Suttonia Coxii*, the first species to bloom, is in flower by the end of August and continues into September during which month there also flower — *Suttonia chathamica*, *Coprosma chathamica* (continuing till February) and *Sophora chatamica.* During October *Corynocarpus* and *Hymenanthera* are in bloom and continue into November which with December forms the most floriferous period of the year since the following amongst others are in blossom: — *Myosotidium*, *Olearia Traversii*, *O. semidentata*, *Veronica gigantea* and the species of *Dracophyllum.* January is also a month of flowers, *O. semidentata* still continues though past its best; *O. chathamica* (commenced December), *Senecio Huntii* (commenced December), *Gentiana chathamica*, *Aciphylla Traversii*, *Sonchus grandifolius*, *Geranium Traversii* and remaining species of *Veronica* are in full bloom. The last-named plants continue on through most of February during which month *Cotula Featherstonii* blossoms. The floral year is closed by the flowering of *Rhopalostylis sapida* in May.

Regarding introduced plants, garden forms of *Narcissi* flower from the end of August to the beginning of October; early potatoes are dug at the end of October or beginning of November; oats sown in August or September are reaped in February; gooseberries are ripe at Christmas and blackberries by the end of January.

4. The Plant-Formations.

a. Coastal formations.

1. Sandy shore.

The leading species are: — *Ranunculus acaulis*, *Calystegia Soldanella* and *Myosotidium nobile.* The last-named was originally extremely abundant and formed a belt just above high-water mark, but it is now extinct in this association.

2. Stony shore.

Where beyond the reach of sheep, pigs etc. *Myosotidium* forms broad colonies which are a remarkable and beautiful spectacle. Its huge leaves have the laminae bent so as to be funnel-shaped and thus an ample supply of water is conducted to the roots during light showers. Other common plants of the association are: — *Urtica australis* forming thickets 30—35 cm high, its stems 1.5 cm in diam. and leaves 15×10 cm; *Rumex neglectus*, *Ranunculus acaulis*, *Crantzia lineata*, *Selliera radicans* and *Cotula potentillina.*

3. Dune.

Extensive dunes occupy a very large part of the Chatham Island coastline. The unstable and semi-stable dune bears a plant-covering similar to that of the mainland with *Scirpus frondosus* and its accompanying species, except that *Spinifex hirsutus* is absent. Where the sand is stable comes dune-forest made up, near the sea, entirely of *Olearia Traversii* and *Suttonia chathamica*, but further inland other trees occur.

Where sand has blown on to flat rock-ledges the endemic *Sonchus grandifolius*[1]) grows luxuriantly (Plate LVI, Fig. 85), and, in its company the endemic creeping, xerophytic grass *Festuca Coxii*, *Salicornia australis*, *Apium prostratum* and *Samolus repens* var. *procumbens*.

4. Cliff and rock.

A rocky coast-line is a frequent feature especially in the S. of the main island and of the smaller islands. Where there is a maximum of spray the endemic *Veronica chathamica*[2]) is characteristic and its companion-plants are: — *Mesembryanthemum australe*, *Apium prostratum*, *Salicornia australis*, *Senecio radiolatus*, stunted *Olearia Traversii* and the endemic *Geranium Traversii*, but this last seems hardly so tolerant of salt. *Blechnum durum*, in less halophytic stations, forms extensive pure colonies.

Near the margin of the great lagoon, there are limestone cliffs, in many places, which, at one time purely littoral, now bear a cevering partly coastal, partly inland. The most striking plant is the endemic *Veronica Dieffenbachii*[3]). Other common plants of this association are: — *Adiantum affine* (in hollows), *Phormium tenax*, *Geranium Traversii*, *Linum monogynum* var. *chathamicum*, *Acaena novae-zelandiae*, *Styphelia Richei* and *Senecio lautus*.

Frequently, flattish rock is covered with peat which varies considerably in depth. In such places, a turf may be formed out of a close growth of, — *Scirpus cernuus*, *Triglochin striata* var. *filifolia*, *Ranunculus acaulis*, *Crantzia lineata*, *Pratia arenaria* and *Selliera radicans*. *Mesembryanthemum australe* is characteristic and may form pure stands. In the N. E. of the island, where the peat is deep, and where certain petrels burrow, are extensive colonies of the endemic *Cotula Featherstonii*[4]) while alongside are great clumps of *Myosotidium* and sheets of *Mesembryanthemum*. In the S. W. of Chatham Island, and on Pitt Island, there is still to be seen the one time more widely-spread

1) A summergreen herb with thick, juicy rhizome, great oblong, pinnatifid or pinnate, pale-green, thick, hard leaves, 30—60 cm long and large flower-head protected by extremely thick, spinous bracts.

2) A shrub with rather thick main-stem, issuing from a crevice, and giving off numerous, supple, slender branches which trail over the rock or hang downwards. The elliptic leaves, 2—2.5 cm long, are rather thick, fleshy, pale-green and more or less downy. There are many distinct forms of the "species" and such may grow side by side.

3) A shrub with far-extending branches, much stouter than those of *V. chathamica*, but nevertheless extremely pliant, and thick, fleshy, pale-green, linear-oblong leaves, 6.5 cm long, confined to the ends of the branches.

4) A biennial herb, 15—30 cm high, greyish in colour and rather like *Matthiola incana*. Its leaves are oblong- or obovate-spathulate 2—5 cm long, soft, pubescent and in rosettes at the ends of the naked branches. The growth-form is quite different to that of the genus in general.

endemic *Coxella Dieffenbachii*[1] but, according to DORRIEN SMITH, it is also a true rock-plant (1910:124).

5. Salt-meadow.

There are extensive salt-meadows in Chatham Island, but unfortunately no account is available of their species. Some of the combinations of halophytes, already given, might be classed as salt-meadow and doubtless the association is composed of the various salt-meadow species of the florula, indeed where the bed of the great lagoon is subject to periodical dryness round patches of *Samolus* are abundant.

6. Lagoon.

The only species recorded for this station is *Ruppia maritima. Zostera* might well be expected.

b. Inland Formations.

1. Rock.

There are no special rock-plants. The most frequent species are the following: — *Cyclophorus serpens*, *Polypodium diversifolium*, *Asplenium flaccidum*, *Phormium tenax*, *Earina autumnalis*, *Linum monogynum* var. *chathamicum*, *Styphelia robusta*, *Veronica Dorrien-Smithii*, *Coprosma* sp. (probably undescribed) and *Olearia chathamica*.

2. Fresh-water.

Lakes and sluggish streams of dark peaty water are abundant but water-plants are few and scarce. The sole species recorded so far are: — *Potamogeton Cheesemanii*, *Polygonum serrulatum*, *Ranunculus rivularis*, *Callitriche Muelleri* and *Myriophyllum elatinoides*.

3. Swamp.

Swamp is essentially a lowland formation. In the deepest water, but rarely mixed, grow *Leptocarpus simplex* and *Carex appressa* var. *sectoides*. Where shallower there is a scrub of *Coprosma propinqua* (dominant), *Blechnum capense*, *Arundo conspicua*, *Deschampsia caespitosa*, *Carex Darwinii* var. *urolepis*, *Phormium*, *Astelia nervosa* (or undescribed species), *Epilobium pallidiflorum* and *E. chionanthum*. As the swamp becomes drier small trees or shrubs appear, especially, — *Coriaria ruscifolia*, and the endemic *Pseudopanax chathamicum*, *Dracophyllum arboreum* and *Suttonia Coxii*[2]). *Hymenanthera chathamica* and *Senecio Huntii* also occur to some extent.

4. Moor.

Moor is specially characteristic of Chatham Island, both in the lowlands and on the table-land. Lowland-moor has been much modified by draining,

1) A perennial herb of the *Aciphylla*-form, but the leaves are neither rigid nor spinous. The flower-stalk measures 60 cm, or more and the leaves are 30 – 60 cm long.

2) A twiggy shrub 3—4 m high, or less, with creeping root or stem and narrow-obovate, coriaceous leaves, 1.8 cm long.

burning and the trampling of stock, so, although it was doubtless very similar to the table-land association[1]), this latter, being quite virgin in places, is alone dealt with here.

The soil consists of peat which varies considerably in its water-content, this latter being reflected in the vegetation, so that the following successive associations can be defined, — *Sphagnum* bog; *Lepyrodia-Olearia* bog; *Olearia-Dracophyllum* bog and *Dracophyllum paludosum* association, this a connecting-link between moor and forest.

Sphagnum bog.

A species of *Sphagnum* forms large, rounded cushions on which grow in the wettest portions, *Scirpus inundatus* and a species of *Carex*. Where a little drier are *Hierochloe redolens*, *Pratia arenaria* and the endemic grass *Poa chathamica*. Other associated plants are, — *Gleichenia dicarpa*, *Eleocharis Cunninghamii*, *Drosera binata*, *Myriophyllum pedunculatum*, *Utricularia monanthos*. The *Gleichenia* frequently establishes wide colonies. Tiny plants of *Dracophyllum paludosum* and *Olearia semidentata* in bloom are not uncommon.

Sporodanthus-Olearia bog.

This association follows *Sphagnum* bog, as soon as the ground becomes a shade drier. The soil is peat, fully saturated with water, and, at a depth of 20 cm, it has the consistency of porridge. The vegetation is extremely dense and consists of *Sporodanthus Traversii*[2]) mixed and entangled with *Olearia semidentata* and *Dracophyllum paludosum*, the mass averaging perhaps 1.5 m in depth.

Olearia-Dracophyllum bog.

This association, which succeeds the last-described as the ground becomes drier, consists of about an equal amount of the *Olearia* and *Dracophyllum* while, in open places, are *Poa chathamica, Drosera binata, Gentiana chathamica* and the *Utricularia.* Possibly *Phormium* was originally an important constituent. When the *Olearia* is in full bloom the brilliant purple flower-heads, in hundreds on every bush, render these Chatham Islands' moors wonderfully beautiful.

Dracophyllum paludosum association.

This is a distinct transition between moor and forest. *D. paludosum* 1.6 m high is dominant and mixed with it here and there trees of *D. arboreum* while juvenile plants of this latter equalling *D. paludosum* in height, but distingiushed by their broad leaves, are abundant. On the ground grow *Poa chathamica, Gentiana chathamica, Pratia arenaria* and seedlings of both species of *Dracophyllum.*

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1) *Gleichenia dicarpa, Sporodanthus Traversii, Dracophyllum paludosum* and *Olearia semidentata* are all present, but I think the last-named was much less abundant than on the table-land.

2) There is a stout rhizome from which arise upright, polished, rush-like stems which branch above into smooth, stiff but flexible terete, smooth branches dull-brown in colour. The Chatham plant is smaller than that of bogs in the Auckland Botanical Districts.

5. Forest.

A very considerable part of both the main island and Pitt Island is occupied by forest of which there are two classes, viz. lowland and upland; the first distinguished by the dominance of *Corynocarpus* and an abundance of *Rhopalostylis* and *Olearia Traversii*, and the second by the absence of the above three trees, the dominance of *Senecio Huntii* and *Dracophyllum arboreum*, and, with the exception of *Veronica gigantea*, a smaller percentage of the other forest-trees than in the lowlands. Shrubs, such a common feature of New Zealand rain-forest, are absent, and the tallest undergrowth consists mainly of the 5 tree-ferns (*Dicksonia squarrosa, D. fibrosa*, *Cyathea Cunninghamii* and *C. medullaris*) and, in some localities, the stems of the liane *Rhipogonum*. On the floor, are many of the usual New Zealand forest-ferns. The lowland forest is generally quite low (6—13 m) and the roof is flat and close, the trees being of equal height. So too, is upland forest low and flat-roofed, except where *D. arboreum* raises its needle-like foliage above the general level. Filmy ferns occur in both classes of forest, but they are most abundant in the upland and may carpet the ground or hide the tree-trunks or fern-trunks. Forest on limestone near the large lagoon is distinguished by the presence of *Sophora chathamica*, absent elsewhere.

6. Heath.

In exposed situations heath succeeds moor as the ground finally becomes fairly dry, or, in many places at the present time, it has seized the ground from which forest has been eradicated by fire. There are two classes of the formation, shrub-heath and bracken-heath.

Shrub-heath is distinguished by the presence of the ericoid shrubs *Styphelia Richei* and *S. robusta*, the rush-like *Scirpus nodosus* and the *Iris*-like *Libertia ixioides. Pimelea arenaria*, or an allied species, is common in some places. Other species are: — *Pteridium esculentum*, *Calamagrostis Forsteri, Danthonia semiannularis*, *Acaena novae-zelandiae*, *Pratia arenaria*, *Helichrysum filicaule* and *Gnaphalium japonicum.*

Bracken-heath frequently consists of pure *Pteridium esculentum* forming dense thickets and attaining a height of more than 1.5 m where more open, various plants of shrub-heath gain a footing and there are transitions between the two associations.

Chapter III. The Vegetation of the Subantarctic Islands.

1. General.

a. Floristic details.

The florula of the New Zealand Subantarctic Islands consists of 187 species, of pteridophyta (34 spp.) and spermophyta (monocotyledons 63 spp., dicotyledons 90 spp.) belonging to 34 families and 88 genera. The largest families with the number of species in each respectively are: — *Filices*, 30; *Grami-*

neae, 28; *Compositae*, 21; *Cyperaceae*, 14; *Orchidaceae* 12; *Juncaceae*, 8; *Rubiaceae* and *Umbelliferae*, 6; and *Caryophyllaceae*, *Cruciferae*, *Ranunculaceae* and *Onagraceae*, 5. The largest genera are: — *Hymenophyllum* and *Poa*, 10; *Blechnum*, *Polypodium*, *Corysanthes*, *Ranunculus* and *Coprosma*, 5 and *Deschampsia*, *Juncus*, *Epilobium*, *Gentiana* and *Cotula*, 4. The following 55 species forming 30 p. c. of the florula are endemic[1]: — *Hierochloe Brunonis*† (A. C.) *Calamagrostis Forsteri* var. *macranthera** (C. Ant.), *Deschampsia gracillima*† (A. C.), *D. penicillata* (M.), *Poa Tennantiana** (S. A. Ant.), *P. antipoda*† (Ant.), *P. litorosa** (S. A. C. Ant.), *P. ramosissima*† (A. C.), *P. Hamiltoni** (M.), *P. aucklandica*† (A. C.), *P. incrassata*† (A. C.), *Atropis antipoda** (Ant.), *Triodia macquariensis*† (M.), *Luzula crinita** (A. C. Ant. M.), *Chrysobactron Rossii** (A. C.), *Urtica aucklandica** (A.), *Stellaria decipiens**, (A. C. M.), *S. decipiens* var. *angustata** (Ant.), *Colobanthus muscoides*† (S. A. C. Ant. M.), *Ranunculus pinguis** (A. C.), *R. subscaposus*† (C.), *R. aucklandicus*† (A.), *Cardamine stellata** (C.), *Geum albiflorum** (A.), *Acaena sanguisorbae* var. *minor** (A. C. Ant. M.), *Epilobium confertifolium** (A. C. Ant.), *E.* sp. aff. *E. alsinoides** (Ant.), *Stilbocarpa polaris** (A. C. Ant. M.), *S. robusta** (S.), *Schizeilema reniforme** (A. C.), *Anisotome latifolia*† (A. C.), *A. antipoda*† (A. C. Ant.), *A. acutifolia** (S.), *Dracophyllum subantarcticum** (C.), *D. scoparium** (C.), *Gentiana cerina** (A. C.), *G. concinna** (A.), *G. antarctica** (C.), *G. antipoda** (Ant.), *Myosotis antarctica** (C.), *M. capitata** (A. C.), *Veronica Benthami*† (A. C.), *Plantago aucklandica** (A), *Pl.* n. sp.* = *P. Brownii* Hook. f. partim (A. C.), *Olearia Lyallii** (S. A.), *Pleurophyllum speciosum*† (A. C.), *P. criniferum*† (A. C. Ant.), *P. Hookeri*† (A. C. M.), *Celmisia vernicosa*† (A. C.), *C. campbellensis*† (A. C.), *Cotula lanata*† (A. C.), *C. propinqua*† (A. C.), *Abrotanella spathulata** (A. C.), *A. rosulata** (C.) and *Senecio antipodus*† (Ant.). The genus *Pleurophyllum* is endemic. It is closely related to *Celmisia* and *Olearia* from which it differs chiefly in habit. The two species of *Celmisia* belong to the subgenus *Ionopsis*. *Stilbocarpa* is common in Stewart Island, but it occurs in the South Island only in S. W. Otago to a most limited degree.

The distribution of the florula in the different groups of islands and the number of species on each is as follows: — Snares, 22; Lord Auckland's, 153; Campbells, 111; Antipodes, 56; and Macquarie, 34.

The elements of the florula fall into the following classes: — (1) Endemic, as above. (2) New Zealand consisting of 123 species (64 p. c.), 62 of which are endemic and of the remainder 41 are also Australian, 20 being pteridophyta and 26 subantarctic South American. (3) Subantarctic South American consisting of 32 species 9[2]) of which do not extend to the main islands of New Zealand.

1) The marks or letters attached to the specific names signify: — * = closely related to New Zealand mainland species, † = not closely related to mainland species; S. A. C. Ant. M. = Snares, Lord Auckland's, Campbell, Antipodes and Macquarie Islands respectively.

2) There are *Festuca erecta, Rostkovia magellanica, Juncus scheuchzerioides* (doubtful), *Ranunculus crassipes, Cardamine glacialis, Acaena adscendens, Callitriche antarctica, Azorella Selago* and *Cotula plumosa*.

The distribution of the New Zealand element according to botanical provinces &c. is: Kermadec 12 (7 pteridophytes); Chatham 42 (20 pteridophytes) Northern 65 (25 pteridophytes); Central 96 (pteridophytes 29); Southern (excluding Stewart district) 112 (pteridophytes 31); Stewart district 105 (pteridophyta 33).

The vertical distribution of the New Zealand element for the remainder of the region is: — Coastal 21; lowland 21; common to both lowland and alpine 47; alpine except at times in far S. 18 and purely alpine 16.

b. The ecological conditions.

The climate is uniform; there is but little difference between the means or extremes of winter and summer temperature. The sky is generally cloudy; showers are frequent; the atmosphere is saturated; periods of sunshine are brief; there is a general average low temperature with but slight winter frosts at sea-level; cold and violent winds accompanied by showers of sleet, hail or even snow are of constant occurrence. The wind indeed is a master-factor. Its mark is on the vegetation everywhere both in regard to form and distribution. The moisture-laden air and lack of sunshine favour the formation of peat. Dead stems and leaves of the herbaceous plants, slowly rotting, remain attached to the living plants. Bryophytes on the ground, on tree-trunks and on rock-faces build thick layers and cushions of peat, the outer shoots alone alive. The ferns, *Blechnum durum* and *Asplenium obtusatum* of the coastal cliffs form, from their dead rhizomes, masses of peat, 30 cm or more in depth, which completely cover the flatter rocks. The soil of all the islands, indeed, for a depth of 9 m, or more, is made up alltogether of plant-remains. Such a soil becomes saturated; pools lie on the surface and holes, masked by vegetation, full of water, are frequent on the open hillsides. The indigenous birds, especially penguins and albatrosses, and the seals, in some of the small islands, play an important part in plant-distribution and where numerous bring about a regular "rotation of crops" (Plate LVII, Fig. 86).

2. The leading Physiognomic Plants and their Growth-forms.

With the exception of the *Metrosideros*, the following physiognomic plants, common to the Subantarctic province and the main islands of New Zealand, need no description: — The herbaceous and filmy ferns, especially *Polystichum vestitum*; *Metrosideros lucida*; *Nothopanax simplex*; *Dracophyllum longifolium*; *Suttonia divaricata* and *Coprosma foetidissima*.

M. lucida (Myrtac.), the southern rata or ironwood is, in New Zealand proper, an erect, evergreen tree with a maximum height of some 18 m, but in Lord Auckland's Islands the trunk is nearly always prostrate (Plate LVIII, Fig. 87) more or less, irregular in shape, bent or arched and far-spreading either on, or just above the forest-floor. The branches, too; are gnarled and twisted and extend more or less horizontally at first, but finally put forth erect branches which ultimately terminate in numerous twigs bearing abundant leaves and so forming flattened or rounded masses. The bark is of a dull reddish-brown and frequently hangs in long strips from the horizontal branches. The leaves are lanceolate to elliptic-lanceolate, 3—5 cm long, thick, stiff, coriaceous and bright-green with a yellow midrib. The flowers are very numerous, bright-crimson and arranged in short terminal cymes.

The purely, or almost, endemic species of physiognomic importance are: —*Danthonia antarctica*[1]), *Poa foliosa*[2]), *P. litorosa*, *Chrysobactron Rossii*, 2 species of *Anisotome*, *Stilbocarpa polaris*, *Dracophyllum subantarcticum*, *Olearia Lyallii* and 3 species of *Pleurophyllum*.

The 3 grasses of the above list are of the tussock form, all build trunks, at times, those of *Poa litorosa* attaining a height of 1.5 m. The leaves of all are coriaceous, those af *P. foliosa* are bright-green and flat, of *P. litorosa* rather stiff, filiform and involute and of *D. antarctica* thick, involute and pale or yellowish green.

Chrysobactron Rossii Hook. f. (Liliac.) is a summer-green herb with a short, stout rootstock and numerous leaves arranged somewhat like those of a garden hyacinth. They are linear, 29 cm $\times$ 9 cm, bright green and fleshy, the outer ones curved outwards and the inner erect but all so bent as to make channels down which water is conducted to the long, thick, fleshy roots. The flowers are dioecious, orange coloured, in dense racemes terminating stout scapes 30 cm, or more long. The male inflorescence may be 10 cm $\times$ 5 cm and is larger and more showy than the female.

Anisotome latifolia and *A. antipoda* (Umbell.) are stately herbs of the *Aciphylla*-form with large, erect, thick, coriaceous, long-petioled, dark-green, pinnate leaves, about 60 cm long, and an inflorescence of compound umbels forming a head of great size, borne on a stout stalk 73 cm high. The two species are closely related but *A. antipoda* has the leaves much more finely divided.

Stilbocarpa polaris (Araliac.) much resembles *S. Lyallii* already described for Stewart Island but there are no stolons, the bright-green, fleshy, coriaceous, orbicular-reniform leaves, 20 cm long $\times$ 30 cm broad, are bristly on both surfaces and there is a stout, branching rhizome, 6 cm (more less) in diam., which creeps along the surface of the ground.

Dracophyllum subantarcticum[3]) (Epacrid.) is of the ordinary erect *Dracophyllum*-form and about 1.5 m high; it needs no special description.

Pleurophyllum speciosum (Compos.) is a semi-summer-green herb of great size with 4—5 bright-green, fleshy, coriaceous, ovate leaves, some 57 cm long $\times$ 39 cm broad, arranged in a cup-like rosette. On the undersurface of the

1) A grass of extremely local distribution on the coast of the North Island is referred by both CHEESEMAN and PETRIE to this species, the former however is by no means sure the two grasses are identical and bases his opinion upon the much smaller dimensions of the North Island grass and its smaller spikelets with fewer florets.

2) Occurs on some of the small islands of the Stewart Island group and in the S. of that island.

3) At present merely a *nomen nudum*.

leaf, at about 10 mm apart, are a number of stout, almost parallel, ribs which are connected by a network of raised, stout veins forming lacunae, in the deep furrows between the ridges filled with loosely entangled cobwebby hairs. The upper surface of the leaf above the veins is sunken and the intermediate parallel spaces are raised, so giving a corrugated appearance to the leaf. The flower-stems are 80 cm, or more, high and terminated by a raceme of 15 flower-heads, each some 5 cm in diam., the disc dark-purple but the rays paler.

P. criniferum Hook. f. is a summer-green herb with thinner, much more erect leaves than the above, 30—90 cm long by 15—30 cm broad, the under-surface loosely tomentose and strengthened by stout flexible ribs. The massive flower-stalk, often more than 1 m high, bears a raceme of globose heads, each 4 cm in diam., the florets purplish-brown.

P. Hookeri Buch. is a semi-summer-green herb with rosettes of obovate, rather thin leaves, about 29 cm long by 6.5 cm broad covered on both surfaces with silvery adpressed silky hairs which render the plant conspicuous.

3. Biology of the Plants.

Since not only are the special subantarctic species considered in what follows but the whole florula, so far as spermophytes and pteridophytes are concerned, and as many species are of restricted distribution, the statistics given are somewhat misleading and do not truly reflect the relation between the growth-forms and the ecological conditions. The abundance of the following growth-forms must therefore be specially emphasized, although some of them are represented by very few species: — 1. *The tussock with a trunk.* 2. *The prostrate tree.* 3. *The divaricating-shrub.* 3. *The cushion.* 4. *The rosette.* 5. *The creeping and rooting herb.* Further, the number of large-leaved herbs is much greater than in any formations of the open elsewhere in the region.

a. Trees.

Trees number 6, all of which, leaving the tree-fern on one side, are frequently shrubs also. The growth-forms are: — Canopy-tree 1; tree-composite 2; araliad-form 1; low bushy-tree 1.

The trunks of 3 species are more or less prostrate for half their length or more, curved, arching or irregularly twisted. In the case of *Olearia Lyallii* and *Senecio Stewartiae* these trunks are firmly anchored to the substratum by adventitious roots. As for *Metrosideros lucida*, roots are abundantly produced from the trunk, but they rarely enter the substratum. However, they branch abundantly in the liverwort covering of the trunk and are thus in a position to take up a good deal of water. *Nothopanax simplex* and *Dracophyllum longifolium* have generally quite short trunks, more or less erect, which are branched from the base; they both stand on the border-land between trees and shrubs.

The leaves of all the trees are thick, coriaceous, stiff (except in the *Senecio*) and glossy (except in *D. longifolium*). Those of *O. Lyallii* and *S. Stewartiae* are large, measuring 20×13 cm and 18×4.5 cm respectively. The otherwise excessive transpiration from the wide surface is checked by a thick tomentum on the under-surface. *Metrosideros lucida*, *Nothopanax simplex* and *Dracophyllum longifolium* have leaves respectively measuring 5×1.9 cm; from 6.5×2 cm to 10.5×3 cm and 16 cm $\times 3$ mm. The last-named has long, narrow leaves tapering to a fine point, sheathing at the base, concave on the upper surface and bunched together, 15 or more at the apices of the ultimate branchlets, after the manner of a tufted grass. They are also vertical or thereabouts and the inner leaves are sheltered by those withered. This strongly xerophytic form leads to the tree occupying the most exposed station in the forest or, as a shrub, growing on wind-swept slopes.

The tree-fern (*Hemitelia Smithii*) must be considered a tree, though in the Aucklands it does not exceed 2 m in height. Its leaves are thin.

b: Shrubs.

Shrubs number 14. Three[1]) are occasionally trees with a distinct trunk. Four are of the divaricating form; 2 of the *Dracophyllum*-form, already described; 4 of the bushy-shrub form; 1 of the low straggling-shrub form; 1 of the mat or flat-cushion form; 1 of the erect, bushy tree-composite form and 1 of the tree-fern form. All, except the *Fuchsia* are evergreen.

All have small, except the fern, coriaceous, except the *Fuchsia*, and ecologically glabrous leaves except those of *Cassinia Vauvilliersii* which are tomentose beneath. The 2 species of *Dracophyllum* have leaves after the manner of those of *D. longifolium*, described above, but those of *D. scoparium* are shorter and thicker and those of *D. subantarcticum* more slender and grasslike. The *Styphelia* has very small, linear, reddish-brown, ericoid leaves, waxy beneath and with recurved margins.

The branches of the shrubs are generally slender; those of the divaricating-form are stiff and more or less rigid; those of the two species of *Dracophyllum* fastigiate and dense, those of *Veronica elliptica* and *Fuchsia* fairly stout, and *Styphelia empetrifolia* has very slender, flexible, wiry branches.

c. Herbs and semi-woody plants.

The number of species belonging to this class is 167, i. e. 89 p. c. of the florula, of which 15 are semi-woody, 20 summer-green, 147 evergreen, 103 spot-bound, 64 wandering, 5 annuals or biennials, 10 epiphytes, 137 herbaceous and about 45 xerophytes or semi-xerophytes.

With regard to size, 2 are very tall (more than 90 cm); 14 tall (60—90 cm); 19 of medium height (30—60 cm); 26 small (15—30 cm); 106 very small less than 15 cm of which 19 hug the ground or are not more than 3 or 4 cm tall.

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1) *Fuchsia excorticata, Veronica elliptica, Coprosma foetidissima.* Not having seen the first-named on the Aucklands I cannot be certain as to whether it should be classed as a tree or shrub.

The growth forms of the 157 herbs and semi-woody plants are as follows: — 1. Annuals 5 consisting of, — tufted-form 3 (grass 1, herbs 2); erect-branching herbs 2. 2. Semi-woody plants 15 consisting of, — *a.* Spot-bound 8 made up of tufted-ferns 4, straggling-form 1, erect branching 1, open cushion-form 2; *b.* Wandering 7 made up of, — erect-branching 2, mat-form 5 (grass 1). 3. Herbaceous 137 consisting of, — *a.* Spot-bound 87 made up of, — tufted-form 34 (ferns 3, grasses 26, rush 1, herbs 4); tussock-form 11 (rush 4, grass 7); rosette-form 22 (all herbs); cushion-form 8; orchid-form 7; straggling-form 2; mat-form 1 (fern); erect-branching 2; *b.* Wandering 50 made up of, — mat-form 28 (filmy fern 4, rush 1, herb 23); erect-creeping 9 (fern 7, grass 2); straggling-grass 1; turf-maker 1 (grass); herb rosette 5; orchid 5, erect-branching herb 1.

The 10 epiphytes are filmy ferns 6; tufted fern 3, and erect semi-woody plant 1.

There is no need to give any details regarding special plants since this is done to some extent both when dealing with the physiognomic species and with the associations. The species of *Anisotome*, with their very large leaves in erect rosettes, are semi-mesophytic or sub-xerophytic representatives of the intensely xerophytic *Aciphyllae* of subalpine and alpine New Zealand. At the same time, their leaf-anatomy shows various xerophytic features[1]).

The chief characteristics of the leaves together with the number of species to each are as follows: — very large (over 20 cm long) 16; large (10—20 cm) 8; of medium size (5—10 cm) 26; small (2.5—5 cm) 44; very small (less than 2.5 cm) 72; thin 82; thick or coriaceous &c. 84; glabrous 145; hairy 21 (tomentose 4).

The most striking fact regarding the leaves of the Subantarctic plants is the occurrence of leaves not only of great size but of distinctly mesophytic character amongst the *endemic* species. This luxuriance is truly remarkable when the wind-factor is considered, but it must be pointed out that the leaves of several are only summer-green or semi-summer-green and that those of some are strengthened by stout veins. Moreover, special luxuriance is in harmony with considerable shelter and decrease in size combined with flattening to the ground comes on in proportion to increase in exposure.

Speaking of some of the endemic species, the roots of *Chrysobactron*, *Anisotome* and *Pleurophyllum* are long, numerous, thick and fleshy. Several, including the cushion-plants (some of these non-endemic) have deeply descending tap-roots. In the case of creeping stems the roots are comparatively short.

The flowers of some of the endemic species show colours almost if not quite unknown in New Zealand proper; examples are: — *Pleurophyllum speciosum* (disc dark-purple, rays whitish-purple); *Myosotis capitata* (brilliant dark-blue), a most beautiful flower; *M. antarctica* (blue); *Veronica Benthami* (blue);

1) *Anisotome latifolia* has thick, wrinkled cuticle; very thick-walled epidermal cells; strong development of stereome below epidermis, continuing through leaf to the vascular bundles; stereome at margin of leaf; 4-layered palisade. *A. antipoda* has cuticle and epidermal cells as above; stomata on both surfaces; subepidermal stereome; dense palisade and pneumatic tissue in centre of leaf.

Epilobium confertifolium (pink); *Gentiana cerina* (white to brilliant crimson); *Celmisia vernicosa* and *C. campbellensis* (disc purple, rays white); *Anisotome latifolia* (pale lilac, rosy-lilac, rosy-purple), *A. antipoda* (bright purple) and *Chrysobactron Rossii* (yellowish-orange). This far-greater proportion of brilliant coloration than elsewhere in New Zealand and the occurrence, too, of brilliantly colored vicarious species, represented by dull-colored in New Zealand, is certainly not due to a greater proportion of insects, but quite the contrary, and even were the insects present, they could do little in the face of constant gales.

d. Seasonal changes.

So far as is known the vegetation is comparatively quiescent from May to the end of September. As the forest and scrub are evergreen the winter and summer aspect are the same except that the leaves of *Histiopteris* are for the most part dead. In the open, where tussock does not dominate, the aspect is considerably changed, for the great leaves of *Pleurophyllum criniferum* and *Chrysobactron Rossii* are absent and those of other species of *Pleurophyllum* much reduced in size. *Hypolepis millefolium* and *Polystichum cystostegia* are likewise summer-green. At about the middle of November, the herbs of Lord Auckland's Islands are just coming into flower the first to appear being those of, — *Ranunculus pinguis*, *R. aucklandicus*, *Myosotis capitata*, *Veronica Benthami* and *Phyllachne clavigera*. By December, many more species are blooming freely and during that month the herb-field is full of of colour, though probably *P. speciosum* is at its best in early January. Then too, *Metrosideros lucida* will turn the forest into a blaze of crimson. More or less of a floral display extends till March but most likely it is chiefly a few species flowering out of season that persist so long, e. g., — *Stilbocarpa*, *Anisotome antipoda*, *Pleurophyllum criniferum*, *Chrysobactron* &c.

4. The Plant-Formations[1]).

a. Coastal formations.

1. Dune.

Dune occurs only on Enderby Island. True sand-binding plants are absent, the wet climate alone keeps the sand fixed and non-dune species form the association, especially, — *Crassula moschata*, *Ranunculus acaulis*, *Epilobium confertifolium*, *Pratia arenaria* and a moss of dense habit. Where the dunes are moving inland, through disturbance by cattle, there are pure colonies of *Rumex neglectus*[2]).

2. Rock and cliff, including stony shore.

The following species occur throughout: — *Blechnum durum* and *Asplenium obtusatum*, which finally form deep masses of peat; *Poa foliosa*, but

1) Macquarie Island is dealt with by itself.

2) Probably absent on the virgin dunes; in New Zealand proper a plant of stony shore and coastal moor.

generally where there is considerable depth of peat; *Scirpus aucklandicus;* green cushions of *Colobanthus muscoides*[1]) growing on solid rock and offering a station for small, shallow-rooting plants; *Callitriche antarctica*, where the rock is wet; *Crassula moschata* and *Veronica elliptica*, this latter frequently on the summit of cliffs. In addition to the above, there occur on Lord Auckland's group and Campbell Island, — *Poa ramosissima* (Plate LIX, Fig. 88), hanging on the cliff in thick, broad, pale, bluish-green sheets; *Montia fontana*, where water drips; and the three subantarctic species of *Cotula*, of which *C. plumosa* is also coastal on Antipodes Island. Certain species occur only on one or other of the islands, e. g.: — *Myosotis albida* (Snares); the endemic *Plantago*[2]) (Aucklands); *Apium prostratum* (Antipodes).

b. Inland formations.

1. Forest.

There are two distinct forest-associations, — the southern-rata and the *Olearia Lyallii*, the latter occurring on the Snares and the Lord Auckland's, the former on the Lord Auckland's only. The remaining groups are without forest.

The southern-rata forest occurs on the Lord Auckland's group as a belt along the shore wherever there is sufficient shelter and extends to a varying altitude up the hills, where it is succeeded by scrub. The trees vary in size according to the degree of exposure, so that, in many places, the forest is little more than scrub. The species number about 49 species of spermophyta and pteridophyta and more than 50 species of bryophyta. There are 3 trees, 6 shrubs, 8 herbs and 32 ferns including 1 tree-fern, 1 semi-tree-fern and 9 filmy ferns. Seen from a distance, the forest appears as a close, homogeneous dull-coloured mass of shrubs rather than trees with a slightly undulating roof of extreme density. Within, the view is truly remarkable. Everywhere are the massive prostrate and semi-prostrate trunks of *Metrosideros lucida* sometimes pressed to the ground, at other times forming great arches, or at others again bridging the deep depressions of the forest-floor. From the trunks branches pass off bent and twisted, in every way conceivable, and forming frequently a rigid tangle. Ultimately, branches arise which pass upwards, branch several times and terminate in close masses of leafy twigs (Plate LX, Fig. 89). Without there will be a boisterous gale, but within the forest all is calm and intense hygrophytic conditions prevail. Thus there is a wonderful wealth of filmy ferns, mosses and liverworts, the first-named forming sheets of delicate green on tree-trunks and floor and the bryophytes forming great cushions or continuous masses on ground or trunks, or covering these with

1) An extremely dense and solid autosaprophytic cushion-plant measuring, at times, 54 cm in diam. The leaves are linear, glabrous, fleshy and about 6 mm long. Within the cushion, there is a mass of yellow, sticky peat into which the peripheral shoots send roots. The cushion absorbs water like a sponge.

2) This grows on solid rock, the fleshy, rather stiff, bright-green almost glabrous leaves forming symmetrical hard, flat rosettes, each about 4 cm in diam.

a thick mantle through which the rhizomes of the filmy ferns ramify. Especially are the yellowish *Dicranoloma Billardieri* and *Plagiochila ramosissima* and *Mastigobryum involutum* conspicuous cushion-builders, while the dark-green *Aneura multifida* makes wide patches on the forest-floor. In many places, there is a close undergrowth which may consist chiefly of the semi-tree-fern, *Polystichum vestitum*, or of *Suttonia divaricata*, the 3 divaricating species of *Coprosma* and *C. foetidissima*. Here and there, the small trees *Dracophyllum longifolium* and *Nothopanax simplex* are abundant.

Olearia Lyallii forest is closely related to *O. Colensoi* coastal-scrub of Stewart Island. On the Snares, it occupies the gullies and more sheltered slopes covering much of the main island. *O. Lyallii* is usually pure, but in places there is a little *Senecio Stewartiae* of similar growth-form. The dominant tree has generally a fairly thick trunk which lies prostrate for half its length, or more. A few more or less horizontal branches are given off, which, branching sparingly, finally bend upwards and branching several times into twos or threes bear, on the ultimate, stiff, white, tomentose branchlets, rosettes of dark-green, very thick, coriaceous, large leaves white beneath with dense tomentum and so close as to touch (Plate LXI, Fig. 90). Seen from within, the forest is about 4.5 m high; trunks sprawl over the ground, sometimes for a distance of 9 m and, everywhere, there is a rigid tangle of stiff, grey branches, while above are naked stems and a close roof of white foliage. Generally, the floor is bare, and undergrowth wanting except at the bottom of a gully where there will be a few plants of *Blechnum durum* and *Polystichum vestitum*.

The association on Ewing Island (Aucklands) is similar, except that the trees are taller (6—9 m), less prostrate and *Senecio Stewartiae* is absent.

2. Scrub.

Scrub occurs where wind or altitude are antagonistic to forest. The formation varies on the different islands and is absent on the Snares, unless the lowest *Olearia* forest be so designated.

Lord Auckland's Islands scrub consists of the forest-trees and shrubs, the former now shrubs merely, with the addition of *Cassinia Vauvilliersii*. Though, in exposed positions, it occurs at sea-level, as on Enderby Island, its greatest development is as a continuous belt on the hills, continuous with the upper forest, at an average altitude of perhaps 150 m. At its upper limit, it merges into tussock-moor, but in the shelter of the gullies it still continues for some time[1]). The chief peculiarity of the association is its astonishing density. The shrubs are so rigid, much-branching and interlaced, that it is frequently impossible to force a passage through, or even to crawl beneath them; the only feasible mode of progression is to roll over their top. *Sut-*

1) The more mesophytic members, e. g. — *Metrosideros* and *Nothopanax* are confined to the gullies, but *Cassinia* and *Dracophyllum longifolium* are dotted amongst the tussocks of the open hillside.

tonia divaricata is dominant and to this especially is the extreme density due. The scrub varies from 1—2 m in height, according to exposure; its surface is uneven.

Dracophyllum scrub is the common scrub-association of Campbell Island. The members are: — *Dracophyllum subantarcticum* (dominant); *D. longifolium*, *D. scoparium* (rare), *Suttonia divaricata*, *Coprosma parviflora*, *C. ciliata*, *C. cuneata* together with *Blechnum capense* and *Polystichum vestitum* when sufficiently open. Seen from a distance, the association presents an even surface and recalls *Leptospermum* heath of the main islands of New Zealand. The relative proportion of *Dracophyllum* or divaricating-shrubs varies in different localities and situations, so that either growth-form may dominate and, in the latter case, the association, according to LAING (1909 : 488) might be called *Coprosma* scrub. *Dracophyllum* scrub is equally as dense as the allied association of the Lord Auckland's from which it differs only in the greater abundance of the *Dracophyllum* form, in the absence of *Metrosideros*, *Cassinia* and *Coprosma foetidissima* and in the presence of the two species of *Dracophyllum*. *Antipodes Island scrub* occurs in the sheltered gullies, descending in long dark lines down the hillsides. It consists of *Coprosma ciliata* and *C. cuneata* and attains a height of about 1.5 m. Probably *Polystichum vestitum* is an associated species.

3. Moor.

"Moor", as here used, includes the various "meadow" and "bog" associations of my previous writings, (1904 and 1909). It occurs throughout the Subantarctic province and embraces two distinct types of association, viz. — tussock-moor and herb-moor.

Tussock-moor.

Tussock-moor consists of 3 distinct associations defined by the presence of *Poa foliosa*, *P. litorosa* or *Danthonia antarctica* as the dominant species.

Poa foliosa moor occurs on the Snares and Aucklands and probably, to some extent, on the Campbell's and Antipodes[1]). The association stands out conspicuously through its bright-green colour. The tussocks are about 50 cm high and 55 cm in diam.; they grow closely and the broad leaves droop somewhat. On the Snares, *Stilbocarpa robusta* is a companion-plant, either singly or in broad patches, its darker-green, great orbicular leaves contrasting with the paler grass. *Asplenium obtusatum* and *Blechnum durum* occur sparingly. On Lord Auckland's Islands, apart from a frequent belt of varying breadth near the shore, where *Carex trifida* is a member, *Poa foliosa* moor exists merely as small pure patches in the *Poa litorosa* association.

Poa litorosa moor is common on the Snares, Campbells, Antipodes and Disappointment Island (Lord Auckland's), but of limited extent on Lord Auck-

1) The Campbell Islands vegetation was by the grazing of sheep &c., so much changed so far as the lower hill-slopes were concerned, before any ecological observations were made, that only a guess can be made as to the primitive tussock-associations. As for Antipodes Island, it has been examined only in a superficial manner.

lands Island itself. Frequently the tussocks are on trunks 57 cm high, but, on the coastal slopes of Antipodes Island, they are 1.5 m high, and grow so closely, that progress can be alone made by stepping from tussock to tussock. On Campbell Island, the association clothes the hillsides, where scrub is absent, to a height of perhaps 150 m. The most important companion-plant, at the present time[1]), is *Chrysobactron Rossii*, which has increased greatly through burning the tussock. Various other species are present, e. g. — *Polystichum vestitum*, dwarf shrubs, especially *Dracophyllum scoparium*, *Pleurophyllum speciosum* and *Veronica Benthami*[2]). On Disappointment Island, many of the herbs of the herb-moor are present, almost black clumps of *Polystichum vestitum* are abundant and, in places, hidden by the tussock, is a close growth of the scrub-shrubs, *Metrosideros* excepted. *Acaena Sanguisorbae* var. *minor* scrambles over the tussocks. On Antipodes Island, where the tussocks are tall, as already described, there is little else, but, where lower, there are masses of *Polytichum vestitum* and, in the shelter this and the tussock afford, a rich vegetation made up chiefly of the following: — many lichens (chiefly species of *Sticta* and *Cladonia*[3]), various bryophytes[4]), *Blechnum penna marina*, *B. capense*, *Asplenium bulbiferum*, *Hypolepis millefolium*, *Hymenophyllum multifidum*, *Lycopodium fastigiatum*, *L. varium* var. *polaris*, *Luzula crinita*, *Stellaria decipiens* var. *angustata*, *Epilobium linnaeoides* and an undescribed species[5]), *Coprosma repens*, stunted *Coprosma cuneata*, *Pratia arenaria* and *Helichrysum bellidioides* var. *prostratum*. The soil of the association throughout its range is deep peat always extremely wet.

Danthonia antarctica moor.

This well-marked association forms the next altitudinal belt after scrub in the Lord Auckland's and after *Poa litorosa* moor in Campbell Island giving, at a distance, a brown colour and smooth appearence to the hillsides. But such smoothness is quite illusory, the ground being most uneven while water lies in hollows of the peat which throughout is extremely wet. The dominant *Danthonia*, of tussock-form, is usually raised above the ground-surface on irregular-shaped, peaty trunks. Shrubs are dotted about[6]), and, in the shelter they and

1) *Chrysobactron* was conspicuous in the virgin vegetation, for HOOKER write (1847: 73) "It covered the swampy sides of the hills in such profusion as to be distinctly visible at a full mile from the shore."

2) An erect, loosely-branched shrub, 20—40 cm high with naked, terete, very flexible branches marked with old leaf-scars, branching near their extremities into short branchlets covered with close-set, coriaceous, thick, bright-green leaves, 2.5 cm long × 1 cm broad and bearing short racemes of violet-blue flowers each 8 mm in diam.

3) *Sticta Freycinetii, S. orygmaea, S. filicina, Cladonia aggregata, C. verticillata, C. pycnoclada, C. gracilis* var. *campbelliana, Stereocaulon argodes* and *Usnea articulata.*

4) *Pallavicinia connivens, Lepidolaena Menziesii, Lophocolea pallida, Metzgeria glaberrima, Tylimanthus homomallus* and *Leptostomum inclinans.*

5) Perhaps *Epilobium antipodum* Petrie.

6) On the Aucklands, *Cassinia Vauvilliersii, Dracophyllum longifolium* and prostrate *Coprosma foetidissima*; on the Campbells the divaricating species of *Coprosma.*

the tussocks afford, are mats of *Coprosma repens* together with *Nertera depressa* *Epilobium linnaeoides*, *E. confertifolium* and *Helichrysum bellidioides* var. *prostratum*.

In places, tussocks without trunks grow so close together that their leaves mingle and the yellow mass, waving in the breeze, looks like a field of ripe corn. But such an apparently pure association, on the Lord Auckland's, may conceal a wiry undergrowth of *Coprosma foetidissima*, *C. cuneata* and *C. parviflora*. When the ground becomes wetter, the tussocks are further apart and there is space for other smaller grasses and many of the smaller herbaceous plants, especially: — *Carpha alpina* (Lord Auckland's), the endemic *Hierochloe Brunonis*, *Deschampsia Chapmani*, *Agrostis magellanica*, *Calamogrostis setifolia*, *Chrysobactron Rossii*, *Ranunculus pinguis*, the endemic *Acaena*, *Epilobium confertifolium*, *E. linnaeoides*, *Celmisia vernicosa*[1]) and *Helichrysum bellidioides* var. *prostratum*.

Herb-moor.

Herb-moor is distinguished by the dominance of other herbaceous growth-forms than tussock which, if not absent, plays a quite subordinate part. It may be divided into the two associations *tall* and *low* herb-moor, the former lowland and not strongly xerophytic and the latter subalpine and xerophytic.

Tall herb-moor, formerly named by me *Pleurophyllum* meadow, occurs in its greatest luxuriance on the shores of Carnley Harbour, and, in a more modified form, on the slopes of Disappointment Island and in Campbell Island. All its members are present in one or other of the formations, but here the array of stately herbs with immense leaves and, in some cases, masses of showy flowers, are gathered together, so that the glory of nearly all the magnificent endemic species can be seen at a glance. "Fairchild's garden" is the most striking example of the association, situated on a sloping piece of ground on Adams Island near the Western channel, and to that charming spot the following specially refers.

The plant-covering presents an irregular surface of varied greens. Near the shore are dark-green masses of *Anisotome latifolia*, knee-deep and deeper, the huge purple inflorescence more than 70 cm high. The great pale-green, corrugated leaves of *Pleurophyllum speciosum*, in loose rosettes, are everywhere, so that one has, most regretfully to trample them underfoot. The bright green leaves of *Poa foliosa* and the brown ones of *Carex appressa* are scattered through the whole. Colonies of *Stilbocarpa polaris* (Plate LXIII, Fig. 92), their fine, round, bristly leaves a vivid green, abound, *Pleurophyllum criniferum* raises up its immense leaves on all sides and its flowering stems 1.5 m high (Plate LXIV, Fig. 93). Blackish patches of *Polystichum vestitum* add a contrast to the prevailing greens. Masses of the orange blossoms of *Chrysobactron Rossii* are everywhere. In places, the beautiful *Gentiana cerina* is plentiful, its delicate

1) A semi-woody plant forming loose cushions 93 cm, or so, in diam. with rosettes 16—4 cm in diam. of excessively glossy, dark-green, stiff, coriaceous linear leaves about 8 cm long and bearing numerous flower-heads 3—4 cm in diam., their disc purple and ray-florets white.

flowers varying from white to crimson. Here and there is the brilliant dark-blue *Myosotis capitata*. Other smaller herbs abound where there is space, e. g., *Epilobium confertifolium*, *E. linnaeoides*, *Acaena Sanginsorbae* var. *minor*, *Coprosma repens*, *Nertera depressa*, *Cotula plumosa* and the *Helichrysum*. Finally; the association shades off into *Danthonia antarctica* moor.

On Antipodes Island, in certain sheltered places there is a distinct association made up of, — the large-leaved *Urtica australis*, *Poa foliosa*, *Polystichum vestitum*, extensive colonies of *Stilbocarpa polaris* and flat-topped bushes of *Coprosma ciliata*.

Ground on Antipodes Island, manured by the giant petrel (*Osstfraga gigantea*) is occupied by the endemic *Senecio antipodus*, a branching perennial herb, 30—60 cm high.

Low herb-moor.

Low herb-moor occurs on sopping wet ground on Lord Auckland's Islands near the summits of the hills. The association consists of species which, almost all, grow close to the surface of the ground. *Pleurophyllum Hookeri* is dominant, the rosettes being frequently so close together that many square metres glisten with the silvery covering. Sometimes the glossy-green cushions or mats of *Celmisia vernicosa* are in vast numbers. *Carpha alpina* and *Astelia linearis* generally form the groundwork of the association. The following are also common: — *Hymenophyllum multifidum*, *Agrostis magellanica*, *Luzula crinita*, *Chrysobactron Rossii*, *Ranunculus pinguis*, *Gentiana cerina*, *Myosotis capitata*, *Veronica Benthami* and *Coprosma repens*.

Where the ground is wettest actual bog-conditions prevail and a sub-association occurs in which the cushion-plants *Phyllachne clavigera* and *Oreobolus pectinatus* are dominant and sub-dominant respectively and the following are common: — cushions of *Gaimardia ciliata*, the rush-like *Schizaea fistulosa* var. *australis*, a turf of *Astelia subulata*, *A. linearis* and *Coprosma repens*. *Celmisia vernicosa* and *Chrysobactron* will also be present. Similar bogs exist on Campbell Island, but these in addition contain *Sphagnum antarcticum*.

On Antipodes Island there are numerous bogs in flat depressions, but their composition as follows is more nearly related to tall herb-moor: — *Marchantia cephalosypha* forms broad, flat patches, *Hymenophyllum multifidum*, *Uncinia riparia* var. *Hookeri*, *Carex ternaria*, *Luzula crinita*, *Anisotome antipoda*, *Stilbocarpa polaris*, *Coprosma repens*, *C. cuneata* (stunted) and *Pleurophyllum criniferum*.

4. Rock and débris.

It is only near the shore and on the summits of the hills in Lord Auckland's Islands and Campbell Island that rocks crop out. The special rock plants are: — *Polypodium pumilum*, *Colobanthus subulatus*, *Geum albiflorum* (Lord Auckland's only), *Schizeilema reniforme* and *Abrotanella rosulata* (Campbells only).

Subalpine rock-association.

On the bare rock is the suffruticose lichen *Stereocaulon ramulosum.* Here also are black patches of several species of *Andreaea.* Peat very readily accumulates on ledges and in hollows so that there is hardly any species belonging to neighbouring formations that does not occur on rock; in fact, *Anisotome antipoda*, *Phyllachne clavigera*, *Coprosma repens* and other species may form a virtually closed association.

Crevice-plants are: — *Cardamine depressa*, *Colobanthus subulatus*, *Geum albiflorum* (Lord Auckland's), *Schizeilema reniformis* and *Abrotanella rosulata* (Campbells). Very characteristic are *Polypodium pumilum* and *Hymenophyllum multifidum* either forming lines in crevices or great sheets on the rock-face. Certain mosses are common on wet rocks, especially, — *Braunia Humboltii*, *Lophiodon strictus*, *Conostomum australe* and *Hypnum hispidum.*

Subalpine rock-débris association.

Beneath the cliffs which form the actual summit of many of the hills of both the Aucklands and Campbells there are débris-fields. But although the primitive substratum would be rock-fragments merely, it would take little time in the wet subantarctic climate before plants settled down, many of which from their peculiar nature would rapidly cause peat to be formed. The substratum is always as wet as possible, so that there is here no need for shingle-slip adaptations; rather is wind-resisting power the chief desideratum, here attained by lowness of stature, the cushion-form, the ground-rosette form and the prostrate-habit. The plants peculiar to the formation, or nearly so are: — *Polystichum cystostegia* (growing where débris is largest), *Marsippospermum gracile*, *Cardamine glacialis* var. *subcarnosa* and *Plantago aucklandica* (Lord Auckland's). The other species are the same as for low moor but the relative percentage is different. *Myosotis capitata*, *Ranunculus pinguis* and *Celmisia vernicosa* are abundant. *Pleurophyllum Hookeri* still plays a most important part.

5. Swamp.

Swamp is a lowland formation. It is especially distinguished by plants of the trunk-tussock form. *Carex trifida*, *C. appressa* and *Poa litorosa* are abundant, the former on the Lord Auckland's and Campbells, and the two latter on Antipodes as well, where *Polystichum vestitum*, in dense masses is very characteristic. *Blechnum capense* is also a frequent swamp plant.

c. Macquarie Island[1]).

On sea-cliffs subject to drenching with salt-water are abundant cushions of *Colobanthus muscoides*, the small endemic grass *Triodia macquariensis* and *Crassula moschata.* This latter and *Cotula plumosa* also occur on the beach.

1) Compiled from the writings of SCOTT (1883) and A. HAMILTON (1895) and CHEESEMAN (The Vascular Flora of Macquarie Island. Scientif. Rep. Austr. Antarc. Exped. ser. C., VII, pt. 3, date?, pp. 1—63).

The Fuegian and Kerguelan *Festuca erecta* is also a plant of coastal rocks. Where the ground is swampy there is a close growth of *Poa foliosa* with tall trunks. If tussock is absent, there is *Cardamine corymbosa*, *Montia fontana* and *Callitriche antarctica*.

The hill-slopes are occupied by a tall growth of *Poa foliosa* tussock, *Stilbocarpa polaris* and the silvery rosettes of *Pleurophyllum Hookeri*; here too is *Acaena adscendens* and *A. Sanguisorbae* var. *minor*. This association is of considerable extent. All the above is distinctly New Zealand-Subantarctic, but on the exposed hill-tops the scene changes; the wind has here the mastery and the formation is allied to the "wind-desert" of Kerguelen Land. Here is HAMILTON'S vivid account: "At about 300 feet you gain a plateau so swept by the antarctic gales that the vegetation is reduced to compact closely growing mosses, small *Uncinias* and the conspicuous cushion-like masses of *Azorella Selago*. In the hollows of the uplands are countless little tarns or lakes, some of considerable extent. Round the tops of the hills the wind has cut out wonderful terraces from a few inches to a foot or two in height, with completely bare rock, much disintegrated by the weather on the top. In some of the more sheltered places or gullies stunted plants of *Stilbocarpa* and *Pleurophyllum* cover the ground."

Ligneous plants are absent, the representative of the subantarctic divaricating species of *Coprosma* being the mat-forming herbaceous or suffruticose *C. repens*.

d) The Bounty Islands.

These consist of a small group of islets and rocks, the largest about 1 km in length and 90 m high. Their sole rock is granite worn smooth as glass by the polishing action for ages of the feet of millions of penguins and many seals. Immense quantities of guano are deposited during the breeding season, but it is washed away by the rains of winter. Except for one species of fresh-water alga, vegetation is absent on the land-surface, but at the shore-line is, in places, abundance of *D'Urvillea antarctica*. Doubtless the islands were once a part of "Greater New Zealand".

Section V.

The Effect of Settlement upon the Plant-Covering of New Zealand.

Chapter I.

The Introduced Plants growing wild without Cultivation.

1. General.

In what has gone before an attempt has been made to give a picture of the plant-covering of primeval New Zealand without regard to that of the region at the present time. In this section, on the contrary, certain aspects of the vegetation, as it now exists, will be briefly dealt with, and some of the fundamental causes discussed which have operated to bring about the vast difference between the New Zealand of 1769 and that of 1920. On this important subject a good deal has been written, some of which contains important data and luminous suggestions, but, on the other hand, erroneous statements have been accepted as truths and misconceptions crept into authoritative scientific writings[1]).

At the time of COOK'S first visit, except for changes wrought by the aborigenes, the vegetation was intact and the flora contained no aliens. To what extent the native race had altered primitive New Zealand it is not possible to determine, but although the population may have considerably exceeded 100,000, its influence on the vegetation would be trifling. Here and there, clearings were made in the forest, or heath, for cultivations[2]), but these were quite small, and though new combinations of species would arise on the cleared ground when abandoned, no permanent associations[3]) of physiognomic importance would originate. On the other hand, judging from the observations of BANKS[4]), the Maori appears to have made considerable use of fire for clearing

1) A. R. WALLACE writes, — "In New Zealand there are more than 250 species of naturalised European plants, more than 100 species of which have spread widely over the country often displacing the native vegetation" (Darwinism 2nd. Ed. 1889 : 15), and on pp. 28, 29 it is stated that, "in New Zealand (white clover) is exterminating many native species, including even the native flax (*Phormium tenax*)."

2) For an account of the cultivation of the only important crop *Ipomaea batatas* see WALSH (1903: 13—20).

3) RUTLAND (1901 : 324—326) shows how *Podocarpus totara* invaded abandoned Maori clearings and considers that much of the forest on the shores of Pelorus Sound is a regrowth.

Various varieties of *Phormium tenax* were frequently cultivated, and COLENSO describes (1881: 19) how he has seen remains of old plantations miles away from any Maori dwelling. Also some of the groves of *Corynocarpus laevigata* are due to the planting of that tree.

4) "Here we saw many great smokes, some near the beach, others between the hills, some very far within land, which we looked upon as great indications of a populous country" ..... "At night we were off Hawke's Bay and saw two monstrous fires inland on the hills. We are now inclined to think that these, and most if not all the great fires that we have seen, are made for the convenience of clearing the land for tillage" (BANKS 1896: 183, 189).

forest etc., so that certain apparently primeval areas, especially *Pteridium*- and *Leptospermum*-heath, and perhaps tussock-steppe, to some extent, may probably have originated from ancient forest-fires. But when we consider the vast areas of undoubtedly virgin forest that only *now* are vanishing, it is clear that *the aborigenes brought about no changes of moment*, and that it was a truly primeval scene that met the gaze of the early botanists. How great the difference in much of the present plant-covering is clearly brought home from the statistics in Chapter III and the details in Chapter II of this section, which show that the greater part of the lowlands has now a plant-covering resembling that of Europe rather than New Zealand, and that there are also wild associations of recent origin composed altogether of exotic plants. Thus, as well as an indigenous flora, there is a second composed of introduced species, some of which are so well attuned to their new environment that they flourish side by side with indigenous plants making new associations, or, in other cases, the exotics, thanks generally to the direct influence of man, have formed pure societies. In other words, a new vegetation and flora are being evolved and various stages of the process are everywhere to hand.

2. Statistical.

The species more or less firmly established in New Zealand are about 513[1]) and belong to 68 families and 279 genera. By far the greater part are European plants, no fewer than 390 belonging to that category. Australian species number only 30, notwithstanding the comparative nearness of that continent; North American 26; South African 17 and the remainder are, for the most part, either tropical or subtropical species of wide distribution or belong to temperate South America.

The families and genera containing the greatest number of species are: — (Families) *Gramineae* 83, *Compositae* 67, *Leguminosae* 44, *Cruciferae* 34, *Caryophyllaceae* 26, *Labiatae* 21, *Scrophulariaceae* 16, *Polygonaceae*, *Ranunculaceae* and *Rosaceae* 13 and *Umbelliferae* 12; (Genera) *Trifolium* 15, *Ranunculus* 11, *Bromus* and *Brassica* 8 and *Rumex* 7.

Coming now to the distribution of the introduced species, 276 occur, though it may be sparsely, in the Northern, Central and Southern botanical provinces, and there are confined to the Northern 94 species, to the Northern and Central together 56, to the Central 21, to the Central and Southern together 18, to the Southern 40 and to the Northern and Southern together 8.

1) This is less than CHEESEMAN's estimate of 528, notwithstanding that here are included certain species he places amongst the indigenous plants in his Flora (e. g. — *Paspalum Digitaria, Stipa setacea, Kyllinga brevifolia, Cyperus tenellus, C. vegetus, Polygonum aviculare, Geranium molle, Gypsophila tubulosa, Taraxacum officinale* &c.), but which in most cases he also considers as introduced, and also a few species recorded since 1906. The plants omitted are in large part those recorded by KIRK as occurring on a ballast-heap, which have not been reported from other localities (see KIRK T. 1896: 501—507). I have also excluded plants which linger in deserted gardens but are not established elsewhere.

The Kermadec Province, according to OLIVER (1910: 173, 174) contains 52 species including *Cordyline terminalis*, *Aleurites moluccana* and *Ageratum conyzoides*, plants not included in my estimate as above, but which are probably introduced. I have insufficient data on which to place an estimate for the Chatham Province, but it must contain more than 60 species. As for the Subantarctic Province, only 25 species have been recorded so far, including *Phormium tenax* and *Acaena Sanguisorbae*, but I doubt if very many more species will be found.

The species themselves differ greatly in their relative abundance and there is a gradual decrease from those of the widest distribution and with ample individuals to such as are only recorded so far from one or two localities, where they just hold their own. Certain species, too, are present in abundance, but they are confined to a definite habitat of perhaps limited extent and others, again, are restricted to the cultivated areas, or to waysides, and really have little or nothing to do with modifying the primitive associations. It is then a most difficult matter to decide as to relative abundance or importance, and I am far from satisfied with the figures about to be given, since species belonging to different categories are counted as equal. About 61 species may be considered extremely common, 33 common, 77 fairly common, 129 local, 136 rare and 77 extremely rare. Adding the last three classes together the total 342 represents no less than 66 p. c. of the introduced flora, the common species forming only 33 p. c. Even, if the local species be excluded from the estimate, *213 species (41 p. c.) are so rare as to be negligable at present.* Perhaps the most widely spread species are *Rumex Acetosella* and *Hypochoeris radicata*, followed, but at some distance, by *Poa pratensis, Holcus lanatus* and *Trifolium repens*. But none of the above are nearly so "aggressive", or have spread so widely under the influence of settlement, as the indigenous *Pteridium esculentum*, *Leptospermum scoparium* or perhaps *Danthonia pilosa* agg. Various forms of *Acaena novae-zelandiae* and *A. Sanguisorbae* are also almost the equal in aggression of any introduced plant. Without giving a full list of the 61 extremely common species, the following may be cited: — *Anthoxanthum odoratum*, *Aira caryophyllea*, *Dactylis glomerata*, *Bromus hordeaceus*, *Chenopodium album*, *Sisymbrium officinale*, *Rubus fruticosus*, *Rosa Eglanteria*, *Ulex europaeus*, *Cytisus scoparius*, *Trifolium dubium*, *Erodium Cicutarium*, *Centaurium umbellatum*, *Bartsia viscosa*, *Plantago lanceolata*, *Erigeron canadensis, Cnicus arvensis*, *Carduus lanceolatus*, *Chrysanthemum Leucanthemum* and *Achillea Millefolium*.

In order to ascertain more fully the position the introduced plants hold in the vegetation a few quite general details can be given as to the habitats they occupy. Of these, one of the most common may be termed "waste-ground", such as occurs on roadsides, on little-used roads themselves, on railway embankments and the like, on unused sections in towns and, indeed, on bare ground generally, where such occurs in the settled districts. Obviously, far more than one habitat is here included, but in the early stages of invasion all are occupied by species the greater part of which are rare or absent elsewhere. Man, in fact, unconsciously causes the establishment of distinct migratory associations. Such waste ground contains about 355 species of which some 255 are confined thereto. If to these are added some 60 species, that are virtually confined to cultivated ground, then it becomes evident that *about 61 p. c. of the introduced flora plays no part as a displacer or replacer of the indigenous vegetation.* Nor is the above estimate high enough, since those of the 102 pasture plants that do not invade the unploughed lands are likewise non-militant, in fact *probably 102 species are all that extend on to those areas where the indigenous vegetation is exposed only to fire, grazing animals and the felling or forest or cutting of shrubs.*

Regarding the growth-forms of the introduced plants, — 15 species are trees, 26 shrubs, 15 lianes, 4 parasites, 17 water-plants, 327 herbs, 92 grass-like plants and 17 rush-like plants. Creeping-stems are the most powerful weapon in the contest for both introduced and indigenous species as shown in *Agropyron repens*, *Rumex Acetosella*, *Cnicus arvensis* and *Pteridium esculentum.*

Chapter II.

Displacement and Replacement of Associations and Species.

1. General.

It is frequently asserted in scientific writings that New Zealand indigenous plants are less fitted for their environment than many of the introduced species, and, that, in consequence, these latter readily displace and replace the former when they come into competition. This is a long way from the actual truth, as the previous chapter has partly shown. *Wherever any part of New Zealand is in its primitive condition and uninterfered with by man or the animals he has introduced, none of the exotics have gained a foothold, their great powers of dissemination notwithstanding, although the virgin area may be pierced in all directions by ground occupied by man where there are introduced species in plenty.* On the other hand, where man has separately, or collectively, brought into play fire, draining, cultivation and introduced domestic or feral animals, he has created a new environment where indigenous and introduced species, if the latter be present, alike go to the wall and new associations arise, or are purposely produced, made up, it may be, purely of exotics, though frequently of such and native plants. Thus, *there are two distinct areas, the one dominated by primitive New Zealand conditions and the other by such as approximate to those of Europe, while between these extremes is a gradual series of intermediates.*

In order to distinguish the directly or indirectly man-made communities from those primitive associations already described in Part II, they are here called "*Induced*" and are subdivided as follows: — 1) *Indigenous-induced*, where the combination consists entirely, or for the most part, of indigenous species, e. g. — *Pteridium* heath; *Veronica* scrub. 2) *Adventitious* [1]), where the species are wholly, or for the greater part, exotic and where the influence of man has been indirect merely e. g. — *Rubus*-thicket; *Digitalis* herb-field. 3) *Artificial*, where definite associations are purposely made by the direct action of man, e. g. — *Eucalyptus* forest; *Alopecurus pratensis-Poa trivialis* meadow. Besides these induced associations, there are also primitive ones more or less changed and containing probably a foreign element but still preserving the original stamp; such are here called "*Modified associations*", e. g. — much of the grass-steppe; milled forest. A distinction must also be drawn concerning those adventitious communities, or even the indigenous-induced which occur as successions both in modified and artificial associations, e. g. — *Danthonia* steppe; *Phormium* swamp after draining *Typha-Phormium* swamp, in fact there are here, as in all classifications, various anomalies. An account of the origin of the many non-primitive associations is beyond the scope of this work, here all that can be given are a few examples of the more important and distinct or of those that may teach some special lesson.

2. Displacement and Replacement.

a. Some specific examples.

1. Displacement of rain-forest by burning and replacement by artificial pasture without ploughing the ground.

At the present lime, from 400 to 800 sq. km of rain-forest, especially in the North Island, are being yearly eradicated and replaced by grassland [2]). The process is of extreme phytogeographical interest since *in one year's time a formation, apparently attuned to a special habitat, is replaced by another ordinarily supposed to depend upon altogether different conditions*, which moreover remains permanent so long, at any rate, as it is kept grazed. The processes involved consist of the following phases: — 1. Felling the forest. 2. Burning the fallen timber. 3. Sowing the seed. 4. Stocking the ground. 5. Burning the old and fallen logs. 6. Stumping the ground.

The forest is felled in winter and early spring. First, the undergrowth is cut and allowed to lie where it falls in order to provide the actual kindling-wood for the succeeding fire. Next, all the trees having a smaller diam. than 90 cm are cut down [3]), the others being left untouched. Burning usually takes place soon after Christmas, but the date depends entirely upon the state of

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1) For short, really "adventitious-induced".

2) During the past thirty years, much of Taranaki has been converted from forest into what is perhaps the finest dairying district in the world. The Kaupokonui dairy factory, with its annual output of 2,000,000 kg of cheese, is only one of many in Taranaki.

3) The procedure differs in different localities. Larger trees are felled on level ground than on steep faces. The cost of felling averages about £ 3„2„6 per hectare.

the weather[1]), since on a successful "burn" depends the future success of the subsequent operations. The lighting of the fires takes place along as long a line as possible at right angles to the wind. Rapidity of burning is essential, so that on a large "block" as many as forty men may be required. Almost before the ashes have stopped smoking, and certainly before they are cold, the seed is sown.

The sowers sow by hand, carrying the seed[2]) in bags, which are ordinary sacks cut half-way down, a flap being thus formed in front, while a hole is cut in the back through which the man thrusts his head. The seed is scattered right and left, both hands being used, and, at each step, a handful of seed is thrown. The sowers form a diagonal line, so that one man slighly overlaps the work of another. The sight of the line of sowers crossing a log-strewn area where walking unburdened is no easy matter for a novice, each carrying a heavy bag and scattering the seed without cessation is not easily forgotten.

The amount sown per hectare varies from 20 to 30 kg. The following are the chief species sown: — *Dactylis glomerata, Lolium perenne, L. italicum, Phleum pratense, Alopecurus pratensis, Poa pratensis, Cynosurus cristatus, Agrostis alba, Trifolium pratense, T. repens, T. hybridum.* Other grasses (*Festuca* spp.) and clovers are occasionally used but the bulk of the seed consists of the first two species in the list[3]). A certain amount of rape, mustard and soft turnip is included in the mixture, so as to provide food for such stock as are turned on to the land within a few months of sowing.

Within 12 months from felling the forest the land is fully stocked and the trampling of the animals consolidates the ground and greatly assists in forming a sward. Where hilly, sheep are generally pastured, but the richer bottom-lands are used for cattle.

By slow degrees, in process of time, the unburned logs decay or are burnt, the standing trees fall, and, if the ground is to be cropped, the stumps are extracted. At present, every stage of the conversion of forest into meadow is to be seen, but there are many areas where no vestige remains of the original plant-covering.

If the grass does not entirely cover the ground, certain indigenous shrubs may become abundant, especially *Aristotelia racemosa.* Also, plants not present in the original vegetation may appear, such as *Leptospermum scoparium* and, near the coast, *Cassinia leptophylla. Pteridium*-heath may also enter in, and were it not for abundant "stocking" would become permanent. Possibly, were the area abandoned, and all animals removed, it would eventually revert to forest.

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1) The following conditions are essential: — 1. The timber must be dry enough. 2. The weather must keep fine during the "burn". 3. The wind must be favourable both in direction and intensity.

2) The seed is packed on horses to the ground from the nearest road in bags containing 35 kg, all the different seeds having been previously mixed together, and they are placed in position over the burnt area.

3) In many localities *Lolium perenne* does not persist, so that eventually *Dactylis* and *Trifolium repens* dominate, and such form the basis of many meadows.

2. Displacement and replacement by adventitious shrub-associations.

Leguminous shrubs.

Ulex europaeus [1]), *Cytisus scoparius*, *Lupinus arboreus* and, to a much lesser degree, *Cytisus candicans* invade open formations replacing and displacing the primitive vegetation. The seeds germinate in the neighbourhood of the parent shrub, and, in the first instance, the invasion of a formation was from shrubs purposely planted. At the present time, there are vast impenetrable thickets of pure (usually) *Ulex* and *Cytisus* on stony river-bed, which when in blossom are a glorious spectacle; both species too are abundant on lowland and lower-montane steppe and fixed dune. At an altitude of 700 m, in the South Island, the above are no longer aggressive.

Lupinus arboreus [2]) is confined to dry sandy or stony stations forming close thickets, 1.8 m or more high, on fixed or semi-stable dunes; it also occurs to some extent on river-bed.

Rosaceous shrubs.

Rosa Eglanteria, *R. canina* [3]), *Rubus fruticosus* agg. and *R. laciniatus* form individually, in many localities, extensive thickets which differ from those of the *Leguminosae* inasmuch as they owe their distribution to birds [4]) while climate restricts *Rubus* to wet and *Rosa* to dry areas.

Rubus thicket is especially aggressive in forest-clearings. Though occurring abundantly in many places, it attains the greatest luxuriance in the Western, North-western, Egmont-Wanganui and Chatham districts.

Rosa thicket becomes readily established on low tussock-steppe, making eventually a pure association. It is specially abundant in the North-eastern district, ascending to about 900 m. In Central Otago it is common on old mining tailings and in gullies in company with *Discaria* and the introduced *Sambucus niger*.

Australian shrubs.

Hakea acicularis [5]), *Epacris purpurascens*, *E. microphylla* and *E. pulchella* form extensive colonies in gumland's-heath, the first-named being wide-spread, but the three epacrids being confined to one locality. The *Hakea* spreads after *Leptospermum scoparium* is burnt and probably the other shrubs first made their appearance after fire.

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1) This was early on introduced as a hedge-plant and is still extensively used for that purpose. Where rarely cut, the hedge exceeds 3.6 m in height and seed is shed in profusion. Burning has no effect in eradicating the plants; seedlings also are produced in millions and grow with great rapidity.

2) This shrub was purposely planted, or sown, on dunes, in the first instance, in order to check drifting sand. This it is unable to do, but it forbids all sand-movement on the ground is occupies.

3) Of local occurrence.

4) Some forms of *Rubus fruticosus* spread vegetatively by means of natural "layering".

5) *Hakea saligna* has also been observed recently.

3. Adventitious tree-associations.

Were no grazing animals present and fires suppressed, it is highly probable that some of the many introduced foreign trees would seize on the open lands, and pine, *Eucalyptus*, *Acacia* and deciduous forests become established.

In the vicinity of clumps of *Quercus sessiliflora*[1]), young plants arise in thousands, and, if not suppressed, soon form thickets. *Acer Pseudo-platanus*[1]) is still more prolific, and its wind-borne schizocarps give greater power of dissemination.

Salix fragilis and *S. babylonica*, planted in the first place on river-banks, now, thanks to the rooting-power of broken twigs &c. line the margins of streams innumerable.

The Californian *Pinus radiata*, in some places, dots the pumice-heath of the Volcanic Plateau and closed associations have arisen in one or two places[2]).

Where gumlands-heath has been burnt, *Eucalyptus globulus* has become established in a few places. At Waitati, near Dunedin, the burning of some dense *Leptospermum scoparium* allowed the seeds from a neighbouring example of *Eucalyptus numerosa* to germinate and there is a close pure tree-association, the *Leptospermum* being altogether suppressed.

Albizzia lophantha is self-established in many parts of the Auckland districts.

Acacia dealbata[3]) is established in a few places, and both on dunes and gumlands increases rapidly by means of suckers.

4. Adventitious water-associations.

The sparsely populated waters of the lowlands are rapidly occupied by foreign water-plants. *Radicula Nasturtium-aquaticum*, introduced as a salad-plant, rapidly seized on flowing streams in which it attains an enormous length of stem and frequently covers the entire water surface.

Ranunculus sceleratus is a most abundant plant of ditches where it forms a pure society.

The Australian *Ottelia ovalifolia* is on the increase in lakes, ponds and shallow streams in the North Auckland district.

Vallisneria spiralis is confined to lake Takapuna, near Auckland City, where it is very abundant in water 1.8 to 2.5 m deep. It owes its origin to one plant placed in the lake in 1885. Not being suitable for bird-carriage, it is not liable to spread beyond the lake which has no connection with any other lakes or streams[4]).

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1) So far as I know, neither of these trees, as yet, have spread spontaneously beyond the original plantation, except into neighbouring hedges.

2) It spreads readily from plantations on low tussock-steppe, the seed being carried a considerable distance by the wind.

3) It is obvious that Australian trees and shrubs, if sufficiently hardy, are much better suited to New Zealand conditions than was supposed. The belief that Australian plants would not thrive was partly based on the statement that BIDWILL was in the habit of habitually scattering Australian seeds during his travels through the country. But we have no evidence as to the nature of the seeds, their age, the soil or locality where scattered or the time of year; indeed the experience of BIDWILL even if a fact proves nothing.

4) See CHEESEMAN 1897: 386—390.

Elodea canadensis is extremely common in certain shallow, slow-flowing rivers of both the North and South Islands.

Perhaps the most interesting case is that of *Ranunculus aquatilis*, which species was not noted until 1905, when it was discovered in South Canterbury. Since then, it has spread to Central Otago, North Canterbury, the North-eastern district and many dune lakes in the southern part of the North Island, its having crossed Cook Strait being a convincing proof that its rapid distribution is owing to water-birds. All plants of disconnected waters must be distributed in a similar manner.

Mimulus moschatus and *M. luteus* are frequent in many shallow lowland and even lower subalpine streams. *Richardia africana* grows luxuriantly in ditches in the Auckland and northern part of the Egmont-Wanganui districts. *Mentha viridis* make pure associations near rivers &c. in many places.

5. Modified Associations.

Steppe.

Frequent burning of the tussock and constant grazing by sheep, cattle, horses and rabbits, where these latter occur, has led to great modifications both from alteration in the relative abundance of the indigenous species and from the introduction of a considerable foreign element. Where burning and stocking in a specially dry area has been excessive, the steppe has been changed to veritable desert. The introduced element varies considerably in different localities, as also at different altitudes. *Anthoxanthum odoratum*, *Holcus lanatus*, *Dactylis glomerata*, *Poa annua*, *P. pratensis*, *Festuca myurus*, *Rumex Acetosella*, *Cerastium viscosum*, *Trifolium repens*, *T. dubium*, *Erodium cicutarium*, *Centaurium umbellatum*, *Plantago lanceolata*, *Achillea Millefolium*, and *Hypochoeris radicata* will probably all be present together, generally, with a good many more foreign plants. Where sheep "camp", there is invariably abundance of *Marrubium vulgare* and perhaps *Urtica urens*. Where roads pass through the dryest steppe, there is a roadside flora of, but all are not usually present at the same time, — *Eschscholtzia californica*, *Reseda luteola*, *Acaena ovina*, *Gilia squarrosa* and *Echium vulgare* [1]), a remarkable assemblage! Also as already noted there may be thickets on the steppe of *Ulex*, *Cytisus scoparius* and *Rosa Eglanteria*.

But it is not the presence of aliens only that distinguishes modified steppe, rather is it the special societies of indigenous species that are evolved and the superabundance of plants normally of second-rate importance or less. Thus, repeated burning will gradually wipe out, or greatly reduce, the tussock and many of the smaller plants, and the ground be eventually occupied by a close turf of *D. pilosa* agg., i. e. the dominant growth-form is changed and indigenous-induced meadow rather than steppe results. Or, again, extensive colonies of *Phormium tenax*, *Pteridium* heath or *Coriaria ruscifolia* may arise.

1) Of course other species enter in, but the above are characteristic.

Certain species of *Acaena*, too, will greatly increase in amount. In wettish parts or shady slopes of montane and subalpine steppe, *Chrysobactron Hookeri* or its var. *angustifolia* will form extensive colonies and, in some localities, *Celmisia spectabilis* will become dominant.

The most interesting case is the transformation of steppe into induced-desert. This has happened in Central Otago and is happening on the Mackenzie Plains and in parts of the North-eastern botanical district. Central Otago, especially below an altitude of 600 m, possesses a very dry climate, owing to the ranges to the W. S. and E. robbing the clouds of most of their moisture. Under a cloudless sky insolation is powerful and the summer hot, so that the district is admirably suited for the growing of peaches, apricots &c. At Clyde, altitude 201 m, the average rainfall is some 38 cm. The rock is schist and the soil light, soft and extremely fertile. In the early days of settlement, both river-valleys and hill-slopes were covered with a continuous mantle of tussocks and their accompanying plants, but it must be pointed out the climate was always arid, as evidenced by the strongly xerophytic character of much of the florula [1]) and the rocks weathered by wind. For more than 60 years, sheep have been depastured on the area and during much of that time there have also been millions of rabbits. Year by year, too, as much of the tussock, as the sheep-farmer was able to burn, he burned. At the present time, as far as the eye can reach, in many places, not a tussock is to be seen, the general aspect is that of naked brown hills not unlike giant dunes. But there are certain plants present, all the same, and, even yet, a considerable number of sheep and innumerable rabbits hold their own, thanks to the presence of the introduced *Rumex Acetosella* and *Erodium Cicutarium* and the fact that at above 700 m altitude there is abundance of vegetation [2]). Continual burning leads finally to the death of the tussock, bare patches of ground become exposed to the wind which whirls the surface-soil high into the air in black clouds. Heavy rain, when it occurs, first of all makes tiny runnels into the soft soil which, converging, form eventually a powerful stream that cuts by degrees a deep trench several metres in depth. As the surface-soil blows away, the stony ground beneath is exposed and this is, in time, captured by the low cushions of *Raoulia lutescens* (Plate LXV, Fig. 94, 95) and the circular mats of *R. australis* and *R. Beauverdii*, all normally river-bed species absent from steppe. Other indigenous species, rare in the original association, enter in, especially the tiny grass *Poa maniototo* and the matted *Stellaria gracilenta* as also introduced species especially *Urtica dioica*, *Erodium*

1) The following may be specially mentioned: — *Carex resectans, Colobanthus brevisepalus, Acaena Buchanani, Carmichaelia Petriei, C. compacta, Hymenanthera dentata* var. *alpina, Pimelea sericeo-villosa, P. sericea, Myosotis pygmaea* var., *Raoulia Parkii, R. Beauverdii.*

2) The climate there being wetter, it is not so easy to burn the tussock (*Poa intermedia* or *Danthonia flavescens*). At lower levels, the difference between sunny and sheltered slopes is most striking, the former being absolutely bare and the latter more or less occupied by *R. Acetosella*, and certain introduced annuals.

Cicutarium, *Festuca myurus*, *Bromus hordeaceus*, the Australian *Agropyron pectinatum*[1]), *Carduus pycnocephalus*, *Cnicus arvensis* and *Vittadinia australis* var.

Modified forest.

After forest has been "milled", and if the ground is not used for farming purposes, the undergrowth forms a dense mass and, in open spaces, foreign plants enter in, especially, — *Rubus fruticosus*, *Cnicus arvensis* and, in some localities, *Arctium Lappa* or *Senecio Jacobaea*. Generally, more or less, fire purposely lit seizes upon the damaged forest, in which case, there will be wide breadths of species of *Erechtites*, the introduced *Erigeron canadensis* and, in most places, an abundant growth of *Aristotelia racemosa*, together with more or less *Fuchsia excorticata* and the lianes *Rubus australis*, *Muehlenbeckia australis* and *Parsonsia heterophylla*. Small pieces of forest, preserved from fire in gullies, maintain in large measure their primitive character, unless overrun by cattle. *The common opinion*, *that once a New Zealand rain-forest is interfered with*, *it is doomed*, *is quite fallacious* and is founded on the fact that such forest generally is destroyed since it falls a prey to fire plus grazing animals and then comes a ground-covering of grasses &c.

Forest, slightly damaged, is frequently invaded by *Sambucus nigra*, the seeds brought by birds, which will replace much of the undergrowth.

Hypericum Androsaemum and, in the North Island, the liane *Senecio mikanioides* (S. Africa) are common just within the forest. *Digitalis purpurea*, in wet localities frequently invades modified rain-forest[2]) or, where this has been destroyed, may occupy extremely wide areas.

Other modified formations.

Unstable dune is modified by the presence of *Ammophila arenaria* and to a much lesser degree *Elymus arenarius*, both of which are planted in the first instance, and afterwards increase by means of seed from which plants dotted here and there arise only to form hillocks to be eventually the sport of the wind.

Dune-hollows support many aliens of waste ground. *Lagurus ovatus*, spp. of *Medicago* and *Melilotus officinalis* are frequently present.

Plantago Coronopus is so abundant in some salt-meadows as to seem indigenous; so too in some places with the grass *Lepturus incurvatus*.

On shingle-beaches, on the northern shore of Cook Strait and near the mouth of the R. Awatere (North-eastern district), there are pure colonies of

1) For further particulars see PETRIE 1912. On one sheep station, according to that author, the number of sheep pastured in 1879 was 75,000 and the number in 1910, 27,231, his table showing a gradual yearly diminution. *Agropyron pectinatum* is local in its distribution.

2) Much more could be written about modified forest, nor can the subject be treated apart from replacement of forest by induced associations. Regarding this, it may be generally stated, that, without the sowing of grass-seed and in the absence of grazing animals, rain-forest is succeeded by growths of shrubs, forest-trees or tree-ferns; lowland beech-forest by *Pteridium*-heath and subalpine by itself replaced, if the surface-humus be not burned, but if this happens and denudation does not follow, then tussock-steppe succeeds.

Glaucium flavum, a striking example of edaphic restriction, since the species is absent on adjacent clay hillsides, except in gravelly situations. So, too, *Verbascum Thapsus* forms pure colonies on denuded river-terrace slopes, fans and the like.

6) Indigenous-induced associations.

Some of these have already been mentioned, particularly, — *Pteridium* heath, *Leptospermum* heath, *Danthonia* meadow, *Cassinia* heath and *Aristotelia* association. Here a few other examples are cited.

When shrub-composite-epacrid scrub of the Western botanical district is burned, a scrub may arise in which *Veronica* is dominant or *Phormium Cookianum* may become abundant.

Forest near the shore of the Stewart Island Inlets, upon being burned, is replaced by pure *Senecio rotundifolius* scrub, but more inland *Dacrydium cupressinum* may be very plentiful.

Where kahikatea forest was felled, and more or less burned near the base of Mt. Alexander, Westland, along the railway, there is now a low almost pure young forest of *Plagianthus betulinus*.

The trampling and grazing of cattle followed by the final close cropping by sheep, in Chatham Island, have transformed shallow swamp to meadow made up principally of the indigenous *Potentilla anserina* var. *anserinoides*, *Crantzia lineata* and *Pratia arenaria* in abundance together with the introduced *Poa pratensis* and also a number of other small indigenous plants. Burning *Olearia-Dracophyllum* moor of the above island may lead to a meadow of *Poa chathamica*, the culms 58 cm high, but such is soon suppressed by wild cattle, if the ground is dry enough to support their weight.

Bare ground caused by cutting away banks on roadsides is, in parts of the South Otago and Stewart districts, rapidly occupied by *Gnaphalium trinerve*, *Nertera depressa*, *Epilobium nerteroides* var. *minimum* and *Gunnera albocarpa*. In the lowland belt of the Western district, similar road-cuttings, if stony, are rapidly occupied by profusion of *Lycopodium volubile* and *Gleichenia Cunninghamii*, and, if less stony, or more sheltered, by the long leaves of *Blechnum capense* almost to the exclusion of all else..

Cutting or burning *Podocarpus dacrydioides* forest leads, as already noted, in the North Island to *Typha* swamp or to a close growth of *Cordyline australis*. *C. indivisa* is produced in the greatest abundance on removal of North Island montane forest, if that species be in the original association. In Campbell Island, *Chrysobactron Rossii* has become enormously plentiful through burning the tussock-moor. Many more examples could be given to show that in modified New Zealand both societies composed of indigenous species may arise on new ground and also various species hold their own and that the foreign element is far from being all-powerful except in European (cultivated) New Zealand.

3. Failure of species to become established.

Most instructive from the phytogeographical standpoint is the apparent inability of many species to establish themselves although apparently most suitable for the purpose. A few examples only can be cited. *Papaver rhoeas*, in various forms, has been cultivated for many years throughout the Dominion and yet it has never become established as a farm-weed. No species ever escaped from my experimental garden near New Brighton where hundreds of plants well suited for dispersal were cultivated and where there was waste land in plenty offering stations of many kinds. Nothing is more common than for the refuse from weeding a flower-garden to be cast on to roadsides in the country and yet the number of species that are so established are negligable. And the converse is also true that species rarely enter a garden from without, and when this does happen such are most likely indigenous plants such as *Pteridium*, *Cordyline australis* or *Coprosma propinqua*.

Even where the seeds of certain aliens are sown regularly as impurities in agricultural seeds the species have never been recorded from any part of New Zealand. There are at least 32 species of this kind, according to a list kindly drawn up for me by the Agricultural Department, the following of which are extremely common as impurities and must be sown freely every year in many parts of the country: — *Carex cephalophora*, *Lepidium intermedium*, *L. virginicum*, *Geranium pusillum*, *Potentilla norvegica*, *Camelina sylvestris*, *Plantago Rugelii*, *P. aristata*, *Centaurea Picris*, *Rudbeckia hirta*.

Chapter III. Agriculture and Horticulture in New Zealand.

1. Agriculture.

New Zealand with its various soils and climates is admirably adapted for different branches of agriculture and horticulture. A full account of how the virgin plant-associations have been displaced or utilized during the past 70 years, and made to yield in exports of agricultural produce a sum of nearly £ 16,000,000 in 1912[1]), would be full of interest, but is far beyond the limits of this chapter.

Primarily, the phytogeographical character of the region has directed the progress of agriculture, forcing it into certain channels. Thus, first of all, apart from the work of the early missionaries and their converts in the far north, the extensive tussock-steppe provided fair pasturage, so that the first progress was in the direction of sheep-farming upon a large scale without in the least attempting to "improve" the land. On the other hand, the dense rain-forests, quite unlike anything the European settler had been accustomed

1) The average value from 1915 to 1919 inclusive was £ 26,000,000, but much of this increase is due to the higher prices ruling than in 1912.

to, seemed to offer an insuperable barrier to agricultural advance. But, with increase of population, and, before all else, with the practical application of certain scientific discoveries, the markets of the world have been brought, as it were, to the very door of the most distant lands, so that from the end of the eighties, in the case of New Zealand, agriculture has advanced by leaps and bounds. No longer did wool form the mainstay of the industry but the production, first of meat, and later of dairy produce, became of prime importance. The small farm, which hitherto had provided a scanty livelihood, became a paying concern, the demand for land increased and still increases, so that such thought to be of no value, or impossible to "reclaim", now yields an abundant harvest, while, above all, certain forest-lands have been converted, at but little cost, into the richest of dairy-farms. Another formation that possessed great agricultural capabilities was the swamp, and this early on through drainage, ploughing and sowing with meadow-grasses, was transformed into pasture quite foreign to the soil. Some swamps, however, were too vast for private enterprise to deal with, but even these are now being subdued by aid of the State. So it comes about that only certain plant-formations remain comparatively undisturbed, especially, — the pumice and gumland's heath, forests too far distant or in too wet a climate for profitable occupation, much of the dune-area and the herb-field of the Southern Alps. But all these, too, are being slowly occupied, so that the time is not far distant when the whole of New Zealand, save the most inhospitable and rugged portions, together with the Natio[illegible]al Parks and similar reserves, will be subservient to the will of man.

The lan[illegible] now being utilized for agricultural purposes falls into the two main classes [illegible] arable and grassland, while this latter must be subdivided into natural and artificial pasture. The last-named, again, comes into the two categories of ploughed and unploughed. Speaking phytogeographically, the arable land and ploughed grassland represent primeval swamp, alluvial steppe, lowland hill-side steppe an[illegible] to some extent forest and even heath, while the unploughed grassland is, for [illegible] greater part, rain-forest converted into pasture by the method described [illegible] the last chapter. The natural pastures represent the original steppe [illegible], th[illegible]itudes now considerably modified by the reduction in number of cert[illegible]genous species, the increase of others and the presence of many foreig[illegible] especially *Hypochoeris radicata* and *Rumex Acetosella*.

The follo[illegible]tics as to the area occupied by the above classes in 1912 are of in[illegible] — 1. Land under crop, 1,729,504 acres[1]). 2. Ploughed grassland 5,00[illegible] 3. Surface-sown (unploughed) grassland 9,214,515 acres. 4. Natural grass[illegible]t 59 p. c. of the area.

The crops grown are those usual in a temperate climate, except in the N. where subtropical plants are cultivated to a limited extent. The most important of temperate products are cereals, of which oats occupying 386,786 acres and wheat 189,869 acres are of far the greatest moment. Of lesser importance

1) Throughout this chapter the metric system is not used; 1 hectare = 2.47 acres.

are, — rye-grass (*Lolium perenne*, *L. italicum*) 63,031 acres; barley 37,486 acres; cocksfoot (*Dactylis glomerata*) 34,007 acres; potatoes 23,480 acres and peas 19,649 acres. Maize, a subtropical crop, occupied 4,683 acres. Grain-growing is carried on to far the greatest extent in Canterbury and Otago (including Southland), the amount of land used elsewhere being of no moment in comparison. Indeed, with regard to crops in general the South Island (principally Canterbury and Otago) plays by far a greater part than the North Island as the following figures show: South 1,416,707 acres; North 312,797. Several of the minor crops are chiefly the product of restricted areas, e. g. — Barley (Nelson and Central Otago); cocksfoot (Banks Peninsula); rye-grass (Western Wellington); hops (Nelson, but only about 700 acres); maize (Auckland 3,961 acres, but elsewhere in the North Island only to a very limited extent[1]). As food for sheep turnips and rape are largely grown, the area being 439,740 acres for the former and 257,155 for the latter.

The yield of the staple crops is a matter of interest. Until quite recent years, no manure of any kind was applied to the land, but, at the present time, various artifical fertilizers are used to a considerable extent. The average yields are as follows: — Oats 46.46 bushels per acre; wheat 27.85; potatoes 5 tons per acre; turnips 12 tons per acre; mangolds 20 tons per acre; peas 30 bushels per acre; maize 46 bushels per acre.

Statistics regarding the live-stock are of no small importance, especially when it is remembered that a considerable part are depastured on the indigenous formations. Figures up to 1912 are unfortunately not available in all cases. Sheep for 1912 numbered 23,750,153 (North Island 12,618,089, South Island 11,132,064), an increase of nearly 5,000,000 since 1903; cattle 2,020,171 of which 79 p. c. belong to the North Island. Taking dairy cattle separately those of the North Island number 591,789 and those of the South Island 212,289. How important the dairy industry has become is shown by the fact that the total production of butter and cheese respectively for 1912 was 576,556 cwt and 606,236, and it must not be forgotten th[illegible] a very considerable percentage came from the land formerly occupied by [illegible] rain-forest. How eminently suited is the soil under exactly the same [illegible] environment for rain-forest, on the one hand, and for rich meadow, [illegible] other, is shown by the fact that within a radius of 20 miles of the [illegible] of Eltham in Taranaki, where 30 years ago rain-forest held undisp[illegible]y, the value of the dairy produce alone is about £ 2,000,000.

2. Horticulture.

Horticulture, since it deals with an unlimited number of species, reflects climatic and edaphic conditions to no small degree. Speaking generally, the lowland climate throughout the region, with the exception of the Subantarctic province, permits the cultivation, in the open air, of many species not hardy

1) Principally grown by the Maoris.

in Europe, except in the S. or in districts possessing a mild insular climate e. g., — *Eucalyptus globulus*, *Acacia melanoxylon*, *Agave americana*, *Hakea saligna*, *Pelargonium zonale*. But the greater part of the plants, whether of flower-garden, kitchen-garden or orchard, are those most commonly cultivated in Great Britain and the garden-fashions of that country, so different ecologically, are for the most part slavishly followed. At the same, almost from the foundation of the Colony, there have been enthusiastic amateur gardeners in the different centres and by them, at one time or another, have been introduced an immense and heterogeneous collection of plants hardy in their several localities. Further, there are a number of semi-botanic gardens where considerable collections of trees, shrubs and herbs have been brought together.

In proceeding from N. to S., leaving on one side the rank and file of the garden species, a considerable change takes place in the flower gardens more especially which is most marked on entering the Southern botanical province on its eastern side and thus quite in accordance with the distribution of the indigenous vegetation.

Various species absent in the South Island, and in many other parts of the North Island, give a special character to the gardens of Auckland. Amongst such are: — *Schinus Molle* which attains a great size especially at Thames, *Bougainvillea glabra*, *Datura cornigera*, *Euphorbia pulcherrima*, the indigenous *Meryta Sinclairii*, *Phytolacca dioica*, species of *Hibiscus*, *Tibouchina semidecandra*, *Ficus macrophylla*, *Erythrina crista-galli*, lemons and oranges. The two latter are grown for commerce, especially near Whangarei. Many species of *Eucalyptus*, not tolerant of frost, grow excellently in lowland Auckland. Napier possesses a climate much the same as Auckland so far as temperature goes, but much drier. Virtually the same subtropical species grow excellently. The horticultural feature of the town is the splendid row of *Araucaria excelsa* along the esplanade. Taranaki has been named the garden of New Zealand. Here, too, many subtropical plants grow luxuriantly. But the chief horticultural features are the splendid vigour of shrubs of all kinds and the rich abundance of Camellias and Chinese Azaleas. By the time the city of Wellington is reached, the subtropical element has weakened somewhat, still it is plainly to be seen in the presence of, — *Ficus macrophylla*, many garden forms of *Fuchsia*, *Lagerstroemia indica*, *Clethra arborea*, species of *Bouvardia*, *Araucaria Bidwillii*, *Boronia megastigma*, many species of *Abutilon*, *Eucalyptus ficifolia* and Himalayan Rhododendrons in great variety.

Turning now to the South Island, various subtropical species can be grown in Nelson and along the coast on the W. to as far S. as Hokitika and probably much further, but on the E., as soon as the Canterbury Plain is gained, the winter frost forbids the presence of all plants which will not tolerate above — 10° C. Thus the trees and shrubs consist largely of species belonging to Europe, as a whole, California and Japan. Many Tasmanian species, too, are quite hardy. Alpine plants are somewhat difficult to cultivate on account of the NW. wind, and this too forbids the use of tree-ferns which can be grown with success in the open in the wetter parts of the North Island. Lowland Banks Peninsula does not answer to the above description, for the climate is much warmer in winter. In Otago, near the coast, the climate of winter is milder than in Canterbury, but the summers are cooler and there is less sunshine. In consequence, more tender species can be grown in many localities e. g., — *Leucadendron argentcum.* The climate especially favours alpine plants so that not only can European, North American and Himalayan species be grown with the greatest ease, but the indigenous plants, much more difficult to cultivate, thrive amazingly. Further S. still, at Invercargill, the great subantarctic herbs grow most vigorously.

Fruit growing is becoming a thriving industry. Apples, pears and plums are grown in all parts of the lowland and montane belts, but for fruit-growing for commercial purposes certain localities are especially suited. The better gumlands' soil of Auckland is suitable for the cultivation of apples, pears, peaches, nectarines, apricots and plums; grapes are also grown to some extent. Oranges and lemons, as already noted, grow well. The area of land occupied by orchards and vineyards in Auckland is 12,035 acres. Apple orchards are rapidly becoming an important feature of Nelson, orchard occupying 4894[1]) acres. The area of land occupied by fruit-trees in Hawke's Bay, Wellington, Canterbury and Otago is respectively, 2421 actes; 3646; 3043 and 4041. Central Otago with its climate, far drier and more sunny than any other part of New Zealand, notwithstanding its winter-cold greater than elsewhere, is specially suited for the well-being of peaches, apricots, nectarines and grapes, so that a flourishing industry has arisen, the green orchards offering a startling contrast to the barren hillsides. The area under orchard in this distant locality is 1662 acres. Here irrigation is being carried out successfully and, before long, much of what is now virtually desert will be transformed into orchards and dairy farms, the latter with lucerne as their main pasture.

A most important branch of agriculture or horticulture is forestry. From the earliest days of settlement, the colonists made plantations and planted belts of trees for shelter especially of *Eucalyptus globulus*, *Pinus radiata* and *Cupressus macrocarpa.* All the deciduous European trees and many other Californian pines have been extensively planted, so that, at the present time, the area occupied by plantations is 63,780 acres. With the rapid destruction of the forests it became plain that afforestation was a necessity. The matter was taken in hand by the Government in 1896, and the work has increased in importance and extent year by year. Using the figures from the Report of the Royal Commission on Forestry 1913, the artificial State forests occupy 18,870 acres[2]) and contain about 44,000,000 trees. The most extensive area

1) 11,002 acres in 1919.

2) The total area of the planted State forests is now (1920) 37,096 acres containing about 77,000,000 trees. The acreage of the different trees is as follows: *Pinus* spp. 21,530; *Larix decidua* 10,103; *Eucalyptus* spp. 2,849; *Picea axcelsa* and *Pseudotsuga taxifolia* 1,285; and Miscellaneous 1,329.

is situated on the Volcanic Plateau, the pumice soil and general climatic conditions, at an altitude of 1000 feet and upwards, being ideal for afforestation purposes. The other areas are in the montane belt of the South Island, principally in Canterbury and Otago, tussock-steppe being the formation replaced. The trees that have been most extensively planted are *Larix decidua*, *Pinus laricio*, *P. austriaca*, several *Eucalypti* the nomenclature of which is not quite certain, *Catalpa speciosa, Quercus sessiliflora* and *Picea excelsa*. Strange to say *Pinus sylvestris* is absolutely worthless for afforestation in any part of New Zealand, the trees early on becoming diseased. So too, the above *Catalpa* has proved quite valueless. The Commission came to the conclusion that of all trees the most important for afforestation purposes was *Pinus radiata*, since it grows with astonishing rapidity in all soils and situations and is ready for conversion at the age of 35 years. Plantations about 30 years old, the trees planted too far apart for making the best timber are now being felled in Canterbury and are yielding 100,000[1]) superficial feet to the acre. *Larix decidua* is of no use for forestry purposes in the lowland belt but the plantations of thus tree at Hanmer (North-eastern district) are splendid. In the dry area of Central Otago several species of *Populus* grow with great vigour.

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1) According to R. G. Robinson (Journ. Cant. Ag. and Past. Assoc., 8, 3 ser. (1920): 10) 60,000 superficial feet is what may be expected.

Part III.

The Flora of New Zealand and its Distribution.

Chapter I. The Botanical Subdivisions of New Zealand.

1. General.

So many areas throughout New Zealand are insufficiently explored, or altogether unknown, so far as plant-distribution is concerned, that few statements as to the range of any species are absolutely valid. Therefore, the classification proposed in this chapter is advanced with great hesitation and offered merely as a provisional attempt to deal with a subject that will be treated with much greater precision by some investigator in the future. In most cases, it is not feasible to fix definite boundaries to the various botanical districts; for not only is there a gradual merging of one into another, but local climates, or edaphic conditions, occur which permit the occasional presence of species, or indeed associations, not in keeping with the general florula, or vegetation.

The major divisions of the region are here designated "*botanical provinces*". These are based largely upon climatic change depending on latitude. For the most part, they correspond to the botanical provinces of my Government Reports, the sole differences being that the boundary-line between the Northern and Central provinces is, in its eastern part, kept somewhat further to the N., and that the South Island portion of the Central province is restricted to the Marlborough Sound's area and some of the country in the immediate vicinity, lying to the W. and to the S.

In dealing with the botanical provinces, the ground is fairly secure, for their basis is the stable one of gradual change in species in proceeding from N. to S. But, when the question of smaller subdivisions, here called "*botanical districts*", comes in, the ground is much less stable, not merely because new discoveries of species, or of distribution, may become disturbing factors, but because facts of various kinds — floristic, ecological and geological — have to be considered.

2. The Botanical Provinces.

The New Zealand region may be naturally divided into the six botanical provinces detailed below. Possibly Norfolk and Lord Howe Islands ought to be included, a course already followed by OLIVER (1910).

1. The Kermadec Province.

This embraces the Kermadec group. The flora is of a fragmentary character and contains not only New Zealand species but others belonging to Norfolk Island, Lord Howe Island and Polynesia, respectively, which are wanting in New Zealand. The total number of species is 115 of which 13 are endemic. The chief characteristic of the vegetation is *Metrosideros villosa* forest containing abundance of the endemic palm, *Rhopalostylis Cheesemanii*.

2. The Northern Mainland Province.

This includes that part of the North Island of New Zealand, as shown on the phytogeographical map, N. of a line[1]) passing from Tauranga to Te Kuiti and thence to Rua Point, together with the various outlying islands including the Three Kings group, but excluding Mayor Island. The total number of species is about 756 of which 87 are confined to the province and to these must be added 33 important species which only penetrate the Central province for a short distance[2]). *Loxsoma*, *Ackama* and *Colensoa* are endemic genera.

Ecologically, the province is specially distinguished by the presence of kauri forest, gumlands' heath and mangrove swamp and, except to a limited extent in the Thames subdistrict, the absence of alpine plants.

3. The Central Mainland Province.

This includes all the North Island to the S. of the southern boundary of the Northern Province together with the area containing the Marlborough Sounds in the South Island and the portion of Marlborough and Nelson lying to the W. as shown on the map[3]). Also the outlying islands together with Mayor island are included. The total number of species is at least 980 of which 69 are confined to the province which is distinguished by the presence of vast taxad-forests of different kinds and also of *Nothofagus* forest both at high and low levels. There is a rich alpine vegetation made up of but few species (174) compared with that of the Southern province. Certain of the more common alpine plants occur in the South Island only in the North-western district[4]) while 33 species, some very characteristic, are confined to the province.

4. The Southern Mainland Province.

Excepting the small portion in the N. E. belonging to the Central Province, the remainder of the South Island is included under this head together with Stewart Island and the neighbouring islands, the Solanders and the Open Bay

1) This is quite provisional.

2) In many respects the most natural line of demarcation would be latitude 38° but this would not fit in with the arrangement as under with regard to the East cape and Volcanic Plateau districts. Were no smaller subdivisions than provinces attempted then, as in my previous writings lat. 38° could be the dividing line.

3) See modification of this statement further on.

4) e. g. — *Pittosporum rigidum*, *Ranunculus insignis*, *Celmisia hieracifolia*, *Leucogenes Leontopodium*, (perhaps), *Senecio Adamsii*.

Islands. The total number of species is more than 1358 of which the large number of 545 is confined to the province. About 60 North Island species are confined to the N. of or do not extend far to the S. of latitude 42°[1]).

Ecologically, there are two distinct areas, the one with a rain-forest and the other with a steppe climate, where forest, except under special circumstances, is absent. The forest contains far fewer species than that of the Northern and Central provinces, but when rain-forest, is essentially of the same subtropical type though its lianes and epiphytes are fewer and its tree-ferns less luxuriant. *Nothofagus* forest is a common feature. The alpine flora is highly developed and consists of 597 species 423 of which are confined to the province.

5. The Chatham Province.

This consists of Chatham and Pitt Islands and the adjacent islets. The flora consists of 240 species, 33 of which are endemic, 20 of which differ in certain minor particulars from the mainland forms. The genera *Coxella* and *Myosotidium* are endemic. (The recently discovered *Cotula Renwickii* is considered in the above estimates).

The principal plant-formations are forest and moor. The forest consists of two classes both made up largely of endemic trees, in the one class the New Zealand *Corynocarpus laevigata* is dominant, and in the other, the endemic *Dracophyllum arboreum* and *Senecio Huntii.* The moor is of different types, but *Sporodanthus Traversii*, *Dracophyllum paludosum* and *Olearia semidentata* are most important constituents.

6. The Subantarctic Province.

This includes all the New Zealand Subantarctic Islands as noted in Part I, Chapter I. The flora consists of 187 species of which 55 are endemic. The plant-associations of these distant groups are far from uniform, but tussock-moor is a most characteristic feature. The genus *Pleurophyllum* is endemic.

3. The Botanical Districts.

1. The Kermadec District.

This corresponds with the Kermadec province as described above. The endemic species are, — *Cyathea Milnei*†[2]), *C. kermadecensis*, *Imperata Cheesemanii*, *Rhopalostylis Cheesemanii*†, *Poa polyphylla*†, *Ascarina lanceolata*, *Boehmeria dealbata*, *Homalanthus polyandrus*[3]), *Rapanea kermadecensis*, *Veronica breviracemosa*†, *Coprosma petiolata*†, *C. acutifolia*†, *Scaevola gracilis*.

1) Were it not that a number of local or strictly South Island species would then be included in the Central Province, a natural arrangement would be to extend the latter so as to take in the lowland flora of the South Island at least as far as Westport, if not Greymouth, on the W. and Kaikoura, if not Banks Peninsula, on the E.

2) Species related to one or other on the New Zealand mainland marked thus †.

3) According to Oliver (1910: 167) this tree has become much more uncommon during the last 20 years, for goats "absolutely determine the existence of the species".

2. The Three Kings District (Northern province).

This includes all the small islands of the Three Kings group. On the West King there is a remarkable low forest of tropical aspect composed of *Meryta Sinclairii* (dominant) mixed with *Cordyline australis* and having *Macropiper excelsum* var. *major* as the important constituent of the undergrowth. The species number 143; the following are endemic: — *Davallia Tasmani*, *Paratrophis Smithii*, *Pittosporum Fairchildii*, *Alectryon grandis*, *Veronica insularis* and *Coprosma macrocarpa*. *Colensoa physaloides* is common in some localities.

3. The North Auckland District (Northern province).

This includes the North Island to the N. of and including the Auckland Isthmus[1]) together with the outlying islands, excluding the two Barrier Islands, but including those of the Hauraki Gulf. The most striking features are the Kauri forest, gumlands' heath and mangrove swamp, in the first-named formation *Beilschmiedia taraire* being frequently dominant. In some places, *Vitex lucens* is a tree of physiognomic importance. The species number 649 of which the following are confined to the district: — *Todaea barbara*, *Lycopodium Drummondii*, *Microlaena Carsei*, *Cladium complanatum*, *Lepidosperma filiforme*, *Carex Brownii*, *Hydatella inconspicua*, *Thelymitra intermedia*, *T. Matthewsii*, *Pterostylis Matthewsii*, *Caleana minor*, *Chiloglottis formicifera*, *Corysanthes Matthewsii*, *Ranunculus hirtus* var. *elongatus*, *Cassytha paniculata*, *Crassula pusilla*, *Pittosporum pimeleoides*, *P. intermedium*, *Ackama rosaefolia*, *Hibiscus diversifolius*, *Halorrhagis cartilaginea*, *Pseudopanax Gilliesii*, *Corokia Cheesemanii*, *Veronica obtusata*, *V. Bollonsii*, *V. ligustrifolia*, *V. acutiflora*, *Coprosma neglecta*, *Alseuosmia Banksii*, *A. linariifolia*, *Olearia angulata* and *Cassinia amoena*.

4. The South Auckland District (Northern Province).

α) The Thames Sub-distict.

This includes the two Barrier Islands and the Thames Mountains to the E. coast together with the outlying islands, excepting Mayor Island, and it extends southwards as far as the southern boundary of the Northern province. The sub-district is distinguished by the presence of extensive kauri-tawa forests, the occurrence of a small alpine plant-community and the first appearance in the N. of actual *Nothofagus* forest, and not merely isolated trees or small clumps. The sub-district also forms the northern limit of a number of southern species. The species number about 648. The following are confined to the sub-district: — *Elytranthe Adamsii*, *Pittosporum Huttonianum*, *Veronica pubescens*, *Olearia Allomii*, *O. arborescens* var. *angustifolia* and *Senecio myrianthos*.

β) The Waikato Sub-district.

This includes the remaining portion of the Northern Province. The most important feature is the extensive swamp formation which, in places grades

1) COLENSO (1869: 9) divided this area into two portions and part of a third, the portion N. of lat. 35° forming his "Northern area". There is a good deal to be said in favour of retaining this latter which should exclude the heavily forested land to the S. Such I would call the Aupori sub-district. (See also CHEESEMAN 1897).

into *Sphagnum* moor. Actual kauri association is of quite small area. There is no alpine association but certain southern plants appear on Mt. Pirongia (960 m), e. g. — *Polypodium novae-zealandiae*, *Cordyline indivisa*, *Enargea parviflora*, *Weinmannia racemosa*, *Nothopanax Sinclairii*, *N. Colensoi*, *Coprosma tenuifolia* and *C. foetidissima*[1]). The number of species is more than 588; only *Althenia Preissii* is confined to the sub-district.

5. The Volcanic Plateau district (Central province).

This occupies the central portion of the North Island. Its boundaries, as shown on the map, are quite provisional. An important ecological feature is that the soil is composed largely of pumice. Much of the area lies at over 600 m altitude, while on Mt. Ruapehu the limit of perpetual snow is reached. There are extensive taxad forests in which *Podocarpus totara* and *P. Hallii* are dominant. Much of the area is occupied by *Leptospermum*-heath with which is abundance of *Dracophyllum subulatum*. *Gaultheria oppositifolia* is also characteristic. Many hot springs, fumeroles &c. occur in the district and in their neighbourhood are special communities and species. In the subalpine belt there is grass-steppe, shrub-steppe and actual desert; *Dracophyllum recurvum* is a most characteristic shrub. The flora consists of more than 702 species of which the following are confined to the district: — *Nephrolepis cordifolia*, *Gleichenia linearis*, *Scirpus crassiusculus*, *Bagnisia Hillii* and *Veronica Hookeriana*.

6. The East Cape District (Central province).

This includes the East Cape peninsula and the area along the coast to a little to the S. of C. Kidnappers. As to the western and southern boundaries, as shown on the map, they are little better than a guess. In the northern part of the district there are extensive forests, both taxad and *Nothofagus*. In the southern part, the climate is dryer than elsewhere in the North Island, forest is rare, and *Pteridium* and *Leptospermum* heath probably the original covering. On the coast, there is a characteristic rock-association of *Veronica macroura* and *Phormium Cookianum* and, on river-banks, a fringe of trees with *Pittosporum Ralphii*, *Sophora grandiflora* and *Hoheria sexstylosa* strongly in evidence. On the mountains, there is a small alpine flora. The species number more than 728, the following being confined to the district: — *Lemna gibba*, *Peperomia reflexa*, *Sophora grandiflora*, *Myosotis amabilis*, *M. saxosa*, *Veronica Darwiniana*, *V. macroura*, *V. Cookiana*, *V. Anagallis*, *Jovellana Sinclairii*, *Utricularia Colensoi*, *Coprosma Solandri*, *Plantago viridis*[2]), *Olearia pachyphylla*, *Senecio perdicioides* and perhaps *Carmichaelia Williamsii*. About 28 South Island species reach their northern limit in this district.

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1) These all occur also in the Thames sub-district.

2) Not yet described; it may be a variety of *Plantago Raoulii*.

7. The Egmont-Wanganui District (Central province).

Here again the boundaries, as shown on the map, are quite uncertain, but the district includes the Wanganui coastal plain together with Mount Egmont. It was originally occupied by most extensive forests, *Beilschmidia tawa* forest being very characteristic. Cliff-vegetation of river-gorges is a striking feature of the district. Mt. Egmont bears quite a rich vegetation, but the alpine species number only about 100; *Ourisia macrophylla* and *Ranunculus nivicola* are extremely abundant. The species number 517; *Senecio Turneri*, *Celmisia glandulosa* var. *latifolia*, a var. of *Carmichaelia australis* and a var. of *Veronica salicifolia* are confined to the district.

8. The Ruahine-Cook District (Central province).

This comprises the Ruahine-Tararua-Rimutaka Mts. and the area to the eastern sea-board together with the small coastal plain W. of the Tararua Mts., the islands in Cook Strait and the Marlborough Sounds area, in the South Island, as shown on the map[1]). There are extensive taxad and beech forests, the latter both lowland and subalpine. The mountain-flora contains nearly all the species of the North Island mountains, and, in addition others belonging to the South Island but absent elsewhere in the North Island, e. g. — *Deschampsia tenella*, *Triodia australis*, *Uncinia fusco-vaginata*, *Drosera stenopetala*, *Aciphylla conspicua*, *Pimelea Gnidia*, *Dracophyllum rosmarinifolium*, *Olearia excorticata*, *O. lacunosa*, *Celmisia hieracifolia* and *Senecio Adamsii*. The total number of species for the district is 800, or more, of which the following are confined thereto: — *Gahnia robusta*, *Carmichaelia odorata*, *Epilobium Cockaynianum*, *Aciphylla oreophila*, *Anisotome dissecta*, *Myosotis Astoni*, *Scutellaria novae-zelandiae* (S. Island only), *Veronica salicifolia* var. *Atkinsoni*, *V. rotundata*, *V. venustula*, *V. Colensoi*, *V. evenosa*, *V. Astoni*, *V. Olseni*, *Coprosma Buchanani*, *Helichrysum Loganii*, *Abrotanella pusilla*, *Senecio Greyi* and *S. compactus*.

9. The North-eastern South Island[2]) District (Southern province).

This includes all the Marlborough Provincial District, excepting the Sounds area, together with that part[3]) of the Nelson Provincial District lying *without*

1) The southern boundary, according to my recent observations, must be extended to the north bank of the R. Wairau (Marlborough). This will bring in the high mountains forming the northern watershed of the Wairau, so far as they lie beyond the average limit of the western rainfall. This extension of the S. Island portion of the Ruahine-Cook district leads to such a considerable addition to the number of alpine plants, that the part of the district in question might well be considered a botanical district itself. However, for the present, I am treating it as a sub-district only, on account of the lowland flora and vegetation agreeing so closely with those of the Wellington portion of the district. The Ruahine-Cook district then is to be divided into the "Wellington sub-district" and the "Sounds-Wairau" sub-district. The following are some of the local endemics of the latter sub-district: *Pimelea Suteri*, *Myosotis Monroi*, *Veronica tumida*, × *V. Simmonsii*, *V. Menziesii* var. *divaricata*, *Celmisia Rutlandii*, *C. Macmahoni* and *Raoulia Gibsii*.

2) In citing these South Island districts the words "South Island" are omitted.

3) Possibly a more natural boundary would be a line from the mouth of the R. Hurunui to the average limit of the western rainfall east of the Hope Saddle.

the area affected by the average westerly rain. The river Waiau marks the southern boundary. The western boundary, as shown on the map, is provisional, and so with all similar boundaries mentioned below.

Except on the eastern side of the Seaward Kaikoura Mts., the district has a highly developed steppe vegetation, the rainfall being lower in relation to altitude than elsewhere in New Zealand, Central Otago excepted. In consequence, there are a number of highly specialized endemic xerophytes. On the steppe-area unless near the coast, forest is absent except at times in gullies, when it consists of *Nothofagus cliffortioides*. There is however luxuriant forest on the E. side of the Seaward Kaikouras containing certain North Island shrubs &c., e. g. — *Rhopalostylis sapida*, *Melicope ternata*, *M. Mantellii* and *Coprosma grandifolia*, so that this portion might be considered a sub-district. This view is supported by the fact of a North Island *Corynocarpus* coastal-forest following the shore-line. The cliff-vegetation of *Olearia insignis*, *Veronica Hulkeana*, *Phormium Cookianum* &c. is a striking feature of the district. The extent of shingle-slip in the mountains is truly remarkable, while fell-field is scanty and most open in character. The species number 722 of which the following are confined to the district: — *Ranunculus lobulatus*, *Geum divergens*, *Chordospartium Stevensoni*, *Nothospartium Carmichaeliae*, *Epilobium rostratum* var. *pubens*, *E. chloraefolium* var. *kaikourense*, *Gunnera cordifolia*, *Schizeilema Roughii*, *Gentiana Astoni*, *Convolvulus fracto-saxosa*, *Cuscuta densiflora*, *Myosotis Cockayniana*, *M. saxatalis*, *Veronica rupicola*, *V. macrantha* var. *brachyphylla*, *Wahlenbergia Matthewsii*, *W. cartilaginea*, *Olearia insignis*, *O. coriacea*, *Celmisia Cockayniana*, *C. Monroi*, *Gnaphalium nitidulum*, *Raoulia cinerea*, *Helichrysum Sinclairii*, *H. Fowerakeri*, *H. coralloides*, *Cassinia albida*, *Senecio Monroi*, *S. Christensenii* and *S. lapidosus*. *Haastia pulvinaris* is especially characteristic, but it extends for a short distance into the North-western district, as indeed may some of the other "endemic" species.

10. North-western South Island District (Southern province).

This lies to the W. of the last-described district and, in its lowland part extends to the Taramakau River, but its high-mountain boundary lies further to the N., as shown on the map[1]).

There is a rich alpine vegetation and flora with extensive herb-fields. Many northern plants reach their southern limit in this district, some of which are absent elsewhere in the South Island[2]). The total number of species for

1) Probably the area to the N. of the R. Buller should be kept distinct as a sub-district, for there the greatest endemism occurs. It is also probable I am making the southern alpine boundary too far to the S., but the botany of the Victoria Range and much of the Spenser Mts. is unknown.

2) For instance, *Lycopodium cernuum*, *Blechnum Fraseri*, *Adiantum aethiopicum*, *Elaeocharis neo-zelandica*, *Cladium capillaceum*, *Astelia Banksii*, *Corysanthes Cheesemanii*, *Calochilus paludosus*, *Pterostylis puberula*, *P. venosa*, *Peperomia Endlicheri*, *Lepidium incisum*, *Pimelea longifolia*, *Dracophyllum latifolium*, *Epacris pauciflora*, *Nertera Cunninghamii* and *Gnaphalium subrigidum*. A

the district is 902 of which the following 32 are confined thereto: — *Carex trachycarpa*, *Centrolepis minima*, *Townsonia deflexa*, *Pittosporum Dallii*, *Carmichaelia Fieldii*, *Rubus Barkeri*, *Aciphylla Hookeri*, *A. Townsoni*, *A. indurata*, *Anisotome diversifolia*, *D. pubescens*, *Myosotis concinna*, *M. Laingii*, *Mitrasacme montana* var. *Helmsii*, *Gentiana filipes*, *G. graciliflora*, *G. vernicosa*, *Veronica divergens*, *V. albicans*, *V. Townsoni*, *V. coarctata*, *Euphrasia Cheesemanii*, *Coprosma obconica*, *Celmisia rupestris*, *C. Gibbsii*, *C. Dallii*, *C. semicordata*, *C. Morgani*, *C. dubia*, *C. parva*, *Senecio glaucophylla* and *S. Hectori*.

11. The Eastern South Island District (Southern province).

This is the continuation southwards of the North-eastern district from which it is distinguished by the absence of the endemic element of the former, the general occurrence of rain-forest at the bases of the foot-hills, the more extensive subalpine *Nothofagus* forest areas, the somewhat closer vegetation of the mountains and the possession of an endemic element, as listed below. Banks Peninsula forms a well-defined sub-district[1]), as also the southerly limit of several northern species[2]). The district, as a whole, is occupied for the greater part by steppe or allied formations. The total number of species is about 822 of which the following 25 are confined to the district: — *Botrychium lunaria*, *Carex cirrhosa*, *C. decurtata*, *Korthalsella clavata*, *Ranunculus Enysii*, *R. Monroi* var. *dentatus*, *R. pauciflorus*, *Carmichaelia prona*, *Pimelea Haastii*, *Epilobium gracilipes*, *Anisotome patula*, *Dracophyllum acicularifolium*, *Myosotis decora*, *Gentiana serotina*, *Veronica Lewisii*, *V. anomala*, *V. amplexicaulis*, *V. Armstrongii*, *V. Lavaudiana*, *V. loganioides*, *Brachycome pinnata*, *Celmisia pseudo-Lyallii*, *C. Mackaui*, *Helichrysum dimorphum* and *Senecio saxifragoides*.

12. The Western South Island District (Southern province).

This extends from the southern boundary of the North-western district to the northern boundary of the Fiord district in the S,[3]) while in the E. it is bounded by a line marking the average limit of the westerly rain and denoted by a forest-covering. The lowlands and mountains up to a height of about 900 m are thickly and continuously covered with forest, mostly taxad on the W. but generally *Nothofagus* on the E. Subalpine-scrub is richly developed; shrub-associations of a subalpine character descend to the lowlands; herb-field is characteristic of the subalpine belt; the most extreme xerophytes are want-

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number of extreme southern plants also here attain their northern limit, e. g. — *Blechnum durum, Microlaena Thomsoni, Ranunculus Lyallii* (only to Paparoa Mts. and Spenser Mts., not N. of R. Buller), *Gunnera albocarpa, Pseudopanax lineare, Anisotome Haastii, Actinotus novae-zealandiae, Gentiana montana, G. saxosa, Veronica Cockayniana, Coprosma serrulata, Leucogenes grandiceps.*

1) The following are endemic, — *Veronica Lavaudiana, Celmisia Mackaui* and *Senecio saxifragoides.*

2) *Adiantum fulvum, Festuca multinodis, Mariscus ustulatus, Rhopalostylis sapida, Macropiper excelsum, Rhagodia nutans, Corynocarpus laevigata, Alectryon excelsum* and *Tetrapathaea australis.*

3) The boundary, as shown on the map, is a mere guess.

ing; *Ranunculus Lyallii*, *Ourisia macrocarpa* var. *calycina*, *Celmisia coriacea*, *C. Armstrongii* and *Senecio scorzoneroides* are extremely abundant; *Quintinia acutifolia* and *Ascarina lucida* are characteristic of lowland forest; the lianes *Metrosideros florida* and *M. scandens* are common and reach their southern limit in the S. of the district. The total number of species exceeds 742 of which the following are confined to the district: — *Calamagrostis Youngii*, *Ranunculus Godleyanus*, *R. Grahami*, *Carmichaelia paludosa*, *Aciphylla similis*, *Myosotis explanata*, *M. suavis*, *Nertera ciliata*, *Veronica Haastii* var. *macrocalyx*, *Brachycome Thomsoni* var. *polita*, *Celmisia Boweana*, *Olearia laxiflora*, *Haastia Greenei* and *Leucogenes Grahami*.

13. The North Otago District (Southern province).

This forms the southern portion of the steppe area of the South Island. It is bounded on the N. by the Waitaki River[1]), on the W. by the eastern limit of the average westerly rainfall and on the S. by the average northern limit of the S.W. rain. The district is the driest in New Zealand. Forest, except in a few gullies in the E., is absent. Much of the steppe of the interior is now induced desert. Generally speaking, the alpine herbs are represented by far fewer individuals than elsewhere in the region for the tussock-grassland extends to the summits of the mountains. The total number of species is probably under 600 of which the following are confined to the district: — *Lepidium Kirkii*, *L. kawarau*, *L. matau*, *Carmichaelia compacta*, *C. curta*, *Myosotis albo-sericea*, *Limosella Curdeana*, *Veronica pimeleoides*.

14. The South Otago District (Southern province).

This occupies the S.E. part of the island subject to the S.W. rain and gales. The boundary between this district and the Fiord district is not at all satisfactory, especially to the W. of Lake Wakatipu. The lowlands are occupied by rain-forest, composed of few species as compared with that of the North Island, *Danthonia Raoulii* steppe and to some extent *Sphagnum*-moor. A considerable number of alpine plants descend to the lowlands, and some play an important part in the associations, e. g. — *Astelia montana*, *Herpolirion novae-zelandiae*. *Metrosideros lucida* is often an important constituent of lowland forest. On the mountains, there are abundant herb-fields. The total number of species for the district is more than 750 of which the following appear to be restricted thereto: — *Poa pygmaea*, *Carex Hectori*, *C. pterocarpa*, *Centrolepis strigosa*, *Luzula micrantha*, *L. leptophylla*, *Gastrodia minor*, *Ranunculus Berggreni*, *R. novae-zealandiae*, *R. pachyrrhizus*, *Acaena Buchanani* var. *longe-filamentosa*, *Carmichaelia virgata*, *Gunnera mixta*, *Tetrachondra Hamiltonii*, *Veronica amabilis*, *Euphrasia umbellata*, *Lagenophora purpurea*, *Olearia Willcoxii*, *Celmisia Poppelwellii*, *C. Thomsoni*, *C. lanceolata*, *Cotula*

1) It would probably be more correct to make the northern boundary further north, and to include at any rate, the whole of the "Mackenzie Country"

Willcoxii and *Senecio southlandicus*. The western highlands of the district possess a number of species otherwise confined to the Fiord district[1]).

15. The Fiord District (Southern province).

This district occupies all the area pierced by the Otago fiords and subject to the extremely heavy westerly downpour. Its eastern and northern boundaries as given on the map are not to be relied upon. The chief characteristics are the presence of *Nothofagus*-taxad forest on the W. and almost pure *Nothofagus* forest on the E.; the well-defined coastal shrub of *Olearia operina*, *Senecio rotundifolius*, *Veronica elliptica* and other shrubs; the extensive herb-fields on the mountains with abundance of *Celmisia Petriei*, *C. verbascifolia*, *Ourisia macrocarpa* var. *cordata* and *Dracophyllum Menziesii* and *Ranunculus Buchanani* on stony ground at high levels. The total number of species for the district is probably over 700 of which possibly the following are confined thereto: — *Agrostis magellanica*, *Danthonia ovata*, *D. planifolia*, *Poa oraria*, *Poa* sp. (decumbent on rock in drip of water), *Elaeocharis acicularis*, *Uncinia tenella*, *Carex plesiostachys*, *Colobanthus Buchanani*, *Ranunculus Matthewsii*, *R. Baughani*, *Pimelea Crosby-Smithiana*, *Epilobium arcuatum*, *Aciphylla multisecta*, *A. congesta*, *Anisotome Lyallii*, *A. capillifolia*, *Myosotis Lyallii*, *Gentiana Matthewsii*, *G. flaccida*, *Veronica Matthewsii*, *Ourisia macrocarpa*, var. *cordata*, *Olearia operina*, *O. Crosby-Smithiana*, *Celmisia holosericea*, *Raoulia Buchanani* and *Senecio bifistulosus*.

16. The Stewart District (Southern province).

This comprises Stewart Island and its adjacent islets together with all the islands of Foveaux Strait and the Solanders.

The most characteristic features of the vegetation are, — two types of forest, the one a rimu-kamahi association and the other swamp-forest of *Dacrydium intermedium*; scrubs of *Senecio rotundifolius* and *Olearia angustifolia* on the coast; lowland *Gleichenia-Hypolaena* moor; mountain vegetation of *Olearia Colensoi* scrub and herb-moor with abundance of cushion-plants; many alpine plants at sea-level; moss-cushions often a most striking feature of forest. The total number of species for the district is 494 of which the following are confined thereto: — *Poa Poppelwellii*, *P. Guthrie-Smithiana*, *Danthonia pungens*, *Uncinia pedicellata*, *Chrysobactron Gibbsii*, *Aciphylla Traillii*, *Anisotome flabellata*, *A. intermedia* var. *oblongifolia*, *Schizeilema Cockaynei*, *Dracophyllum Pearsoni*, *Veronica Laingii*, *Ourisia modesta*, *Olearia divaricata*, *Celmisia glabrescens*, *Abrotanella muscosa* and *Raoulia Goyeni*. The following are almost endemic: — *Stilbocarpa Lyallii*, *Olearia angustifolia* and *O. Traillii*. Certain species of the Subantarctic district occur which are absent on the mainland[2]).

1) For instance, — *Deschampsia pusilla*, *Ranunculus Buchanani*, *Aciphylla Kirkii*, *A. pinnatifida*, *Dracophyllum prostratum*, *Veronica Petriei*, *V. dasyphylla*, *V. Birleyi*, *V. Muelleri*, *Olearia oleifolia*, *Celmisia Petriei*, *C. verbascifolia*, *C. ramulosa*, *Senecio revolutus*.

2) *Polypodium Billardieri* var. *rigidum*, *Asplenium scleroprium*, *Poa foliosa*, *Astelia subulata*, *Urtica australis*, *Veronica odora* and *Senecio Stewartiae*.

17. The Chatham District (Chatham province).

This corresponds to the Chatham province as described above. The species number 240, those confined to the district are as follows: — *Poa chathamica*, *Festuca Coxii*, *Carex appressa* var. *sectoides*, *C. Darwinii* var. *urolepis*, *Phormium tenax* var. with thin, drooping leaves, *Geranium Traversii* and var. *elegans*, *Linum monogynum* var. *chathamicum*, *Plagianthus betulinus* var. *chathamicus*, *Pseudopanax chathamicum*, *Aciphylla Traversii*, *Coxella Dieffenbachii*, *Corokia macrocarpa*, *Styphelia robusta*, *Dracophyllum arboreum*, *D. paludosum*, *Suttonia Coxii*, *Gentiana chathamica*, *Myosotidium nobile*, *Veronica Dieffenbachii*, *V. Barkeri*, *V. Dorrien-Smithii*, *V. chathamica*, *V. gigantea*, *Coprosma chathamica*, *Olearia semidentata*, *O. chathamica*, *O. Traversii*, *Cotula potentillina*, *C. Featherstonii*, *C. Renwickii*, *Senecio radiolatus*, *S. Huntii* and *Sonchus grandifolius*.

18. The Snares District[1]) (Subantarctic province).

This includes the Snares Group. The characteristic features are a scrub-forest of *Olearia Lyallii* and tussock-moor of *Poa litorosa* and *P. foliosa*. The species number only 22 of which *Stilbocarpa robusta* and *Anisotome acutifolia* are endemic.

19. The Lord Auckland's District (Subantarctic province).

This district includes all the islands of the Lord Aucklands group. It is distinguished from the other subantarctic districts by the presence of *Metrosideros lucida* forest. Scrub, tussock-moor and herb-moor are well developed. The species number 152 of which the following are confined to the district: — *Urtica aucklandica*, *Ranunculus aucklandicus*, *Geum albiflorum*, *Gentiana concinna*, *Plantago aucklandica*.

20. The Campbell District (Subantarctic province).

This includes Campbell Island and its islets. Forest is absent but there is fairly tall (in places) *Dracophyllum*-scrub. The moor-associations differ from those of the Lord Auckland's district only in certain floristic details. The number of species is 110 of which the following are confined to the district: — *Ranunculus subscaposus*, *Dracophyllum subantarcticum*[2]), *D. scoparium*, *Gentiana antarctica*, *Myosotis antarctica* and *Abrotanella rosulata*.

21. The Antipodes District (Subantarctic province).

This includes Antipodes and Bollons Islands and a few rocks. Scrub is reduced to a few low patches the vegetation being almost entirely tussock-moor. The species number 56 of which the following are confined to the district: — *Atropis antipoda*, *Stellaria decipiens* var. *angustata*, *Epilobium* sp. (*E. alsinoides* T. Kirk non A. Cunn.), *Gentiana antipoda* and *Senecio antipodus*.

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1) But for the general ecological character of the vegetation and the presence of *Colobanthus muscoides* this might be united phytogeographically to the Stewart district.

2) So far a *nomen nudum*.

22. The Macquarie District (Subantarctic province).

This includes Macquarie Island and its outlying rocks. Woody plants are absent. The vegetation consists of tussock-moor and cushion-moor of *Azorella Selago.* The species number 34 of which the following are confined to the district: — *Deschampsia penicellata*, *Poa Hamiltoni*, *Festuca erecta**[1]), *Triodia macquariensis*, *Ranunculus crassipes**, *Acaena adscendens**, *Azorella Selago**.

Chapter II. The Families, Genera and Elements of the Flora.

1. The General Statistics.

The total number of species of vascular plants, together with such varieties as are of equal rank to many admitted species, is 1771[2]) of which 162 are pteridophyta (Filices 144), 397 monocotyledons and 1212 dicotyledons which are contained in 381 genera belonging to 105 families. The species as in all floras are not of equal rank, but all transitions exist from those which are undoubted aggregates to such as the more conservative taxonomists would unite into one comprehensive species. If this were done the total would sink to 1490 or 81 less then CHEESEMAN's estimate in 1906. In any case the flora is not nearly so "poor" as was considered by WALLACE[3]), nor would the figures be so different from those of the British flora with which that distinguished author compares it, according to The London Catalogue of British Plants (1908)[4]), were the genera *Veronica*, *Celmisia* and others to be dealt with in the same spirit as regards *Rubus* and *Hieracium*.

Coming now to certain details[5]), the average number of species to each family is nearly 17.8 and to each genus 4.8. The largest families and genera are as follows: — (Families) *Compositae* 259 species of which 25 are aggregates, *Filices* 144 (aggs. 12)[6]), *Scrophulariaceae* 146 (aggs. 30), *Gramineae* 127 (aggs. 14), *Cyperaceae* 124 (aggs. 11), *Umbelliferae* 78 (aggs. 7), *Orchidaceae* 60 (agg. 1);

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1) The star (*) indicates that the species is also subantarctic South American.

2) This total includes not only all the species I believe to be "valid", published since the issue of Cheeseman's Manual in 1906, but a few others which I propose to describe in the near future. At the same time, it must be remembered that the flora is by no means fully investigated and that species in no small number are being yearly described. Further, critical work on the "variable" genera is in its infancy, and undoubtedly the different aggregate species will, in time, be split up. Leaving however this latter class out of consideration, it is quite possible that from 50 to 100 additional well-marked species of spermophyta are contained in the flora.

The above paragraph was written in February, 1914; since then about 69 additional species have been described, thus bringing the total to 1840.

3) Island Life 1892: 488—489.

4) The total excluding *Characeae* is 2047 of which 133 belong to *Hieracium* and 116 to *Rubus*.

5) The figures which follow are based on 1840 as an estimate up to the year 1920 of the total number of species.

6) Means aggregate species. This term I use with a rather wide significance.

Ranunculaceae 57 (aggs. 7); *Rubiaceae* 52 (aggs. 8); *Onagraceae* 43 (aggs. 8); *Epacridaceae* 40 (aggs. 3); *Leguminosae* 35 (aggs. 5); *Borraginaceae* 32 (aggs. 3); *Juncaceae* 30 (aggs. 3); *Rosaceae* 27 (aggs. 6); *Cruciferae* 25 (agg. 1); *Gentianacae* 24 (aggs. 2); *Halorrhagaceae* 22 (aggs. 2); *Pittosporaceae*, *Myrtaceae* and *Caryophyllaceae* 20 (aggs. 2, 2 and 2); *Araliaceae* 19 (agg. 1), *Taxaceae* and *Thymelaeaceae* 17 (aggs. 3 and 3); *Campanulaceae* 14 (aggs. 4); *Chenopodiaceae* 13; *Violaceae* and *Lycopodiaceae* 12 (aggs. 3 and 0); (Genera) *Veronica* 108; *Carex* and *Celmisia* 55; *Ranunculus* 46; *Coprosma* and *Olearia* 43: *Epilobium* 40; *Senecio* 34; *Myosotis* 31; *Poa* 30; *Dracophyllum* 27; *Aciphylla* 25; *Cotula* and *Gentiana* 23; *Carmichaelia* 22; *Hymenophyllum*, *Raoulia* and *Pittosporum* 20; *Anisotome* 19; *Asplenium*, *Danthonia*, *Scirpus*, *Uncinia*, *Juncus* and *Helichrysum* 15; *Blechnum* and *Pimelea* 14; *Luzula*, *Acaena* and *Euphrasia* 13; *Pterostylis* 12, *Lycopodium*, *Calamagrostis*, *Thelymitra*, *Colobanthus*, *Metrosideros* and *Ourisia* 11.

Although the above figures show the relative importance of the larger families and genera, so far as the flora is concerned, they exaggerate the part that some play in the vegetation. In this regard many small genera are of more moment although they may be of restricted distribution; the following to which the number of species are appended are examples: — *Cyathea* 5, *Hemitelia* 1, *Dicksonia* 3, *Pteridium* 1, *Gleichenia* 6 (Filices); *Agathis* 1, *Libocedrus* 2 (Pinac.); *Typha* 1 (Typhac.); *Freycinetia* 1 (Pandanac.); *Arundo* 2 (Gramin.); *Mariscus* 1, *Schoenus* 7; *Gahnia* 8 (Cyperac.); *Rhopalostylis* 2 (Palmae); *Leptocarpus* 1, *Hypolaena* 1 (Restionac.); *Rhipogonum* 1, *Cordyline* 4, *Astelia* 9, *Phormium* 2, *Chrysobactron* 3 (Liliac;.) *Nothofagus* 6 (Fagac.); *Elatostema* 1 (Urticac.); *Elytranthe* 4 (Loranthac.); *Muehlenbeckia* 5 (Polygonac.), *Carpodctus* 1 (Saxifragac.); *Weinmannia* 2 (Cunoniac.); *Rubus* 7 (Rosac.); *Sophora* 4 (Legumin.); *Coriaria* 4 (Coriariac.); *Pomaderris* 4, *Discaria* 1 (Rhamnac.); *Aristotelia* 3 (Elaeocarp.); *Plagianthus* 3, *Hoheria* 3, *Gaya* 2 (Malvac.); *Melicytus* 4 (Violac.); *Leptospermum* 4, *Myrtus* 4 (Myrtac.); *Fuchsia* 3 (Onagrac.); *Nothopanax* 7, *Pseudopanax* 7, *Schefflera* 1 (Araliac.); *Griselinia* 2 (Cornac.); *Gaultheria* 6 (Ericac.); *Styphelia* 8, *Epacris* 2 (Epacridac.); *Rapanea* 3, *Suttonia* 5 (Myrsinac.); *Olea* 4 (Oleac.); *Geniostoma* 1 (Loganiac.); *Parsonsia* 2 (Apocynac.); *Vitex* 1, *Avicennia* 1 (Verbenac.); *Myoporum* 1 (Myoporac.); *Nertera* 6 (Rubiac.); *Alseuosmia* 4 (Caprifoliac.); *Selliera* 1 (Goodeniac.); *Pleurophyllum* 4, *Haastia* 4, *Leucogenes* 3, *Cassinia* 6, *Brachyglottis* 2 (Compositae).

In contradistinction to the above, the following genera are so rare that their absence from the vegetation would not be noticed: — *Simplicia* 1, *Amphibromus* 1 (Gramin.); *Hydatella* 1 (Centrolepidac.); *Iphigenia* 1 (Liliac.); *Bagnisia* 1 (Burmanniac.); *Caleana* 1 (Orchidac.); *Phrygilanthus* 2 (Loranthac.); *Myosurus* 1 (Ranunculac.); *Logania* 1 (Loganiac.); *Cuscuta* 1 (Convolvulac.) and *Tetrachondra* 1 (Labiatae).

A considerable number of genera, perhaps more than 25 p. c., are extremely variable, the variation being in part epharmonic and in part more or less hereditary under considerable changes of environment. Between epharmonic and hereditary variation it is, in many cases, hard to draw the line. This great variation makes the delimitation of species extremely difficult in no few genera, so that no two taxonomists working with the same material could possibly arrive at similar conclusions. The following genera are specially variable[1]) throughout the whole of their range: — *Asplenium* (Filices), *Calamagrostis*, *Deschampsia*, *Danthonia*, *Koeleria*, *Poa*, *Festuca*, *Agropyron* (Gramineae), *Scirpus*, *Uncinia*, *Carex* (Cyperac.), *Juncus*, *Luzula* (Juncac.), *Phormium* (Liliac.), *Muehlenbeckia* (Polygonac.), *Colobanthus* (Caryophyllac.), *Clematis*, *Ranunculus* (Ranunculac.), *Cardamine* (Cruciferae), *Pittosporum* (Pittosporac.), *Rubus*, *Acaena* (Rosac.), *Carmichaelia*, *Sophora* (Legum.), *Oxalis* (Oxalidac.), *Coriaria* (Coriariac.), *Aristotelia* (Elaeocarpac.), *Hoheria* (Malvac.), *Pimelea*, *Drapetes* (Thymelaeac.), *Leptospermum* (Myrtac.), *Epilobium*, *Fuchsia* (Onagrac.), *Halorrhagis*, *Gunnera* (Halorrhagac.), *Apium*, *Hydrocotyle*, *Aciphylla*, *Anisotome* (Umbel.), *Gaultheria* (Ericac.), *Dracophyllum* (Epacridac.), *Gentiana* (Gentianac.), *Myosotis* (Borraginac.), *Veronica*, *Ourisia*, *Euphrasia* (Scrophulariac.), *Plantago* (Plantaginac.), *Coprosma* (Rubiac.), *Alseuosmia* (Caprifoliac.), *Wahlenbergia* (Campanulac.), *Forstera* (Stylidiac.), *Lagenophora*, *Olearia*, *Celmisia*, *Cotula*, *Gnaphalium*, *Helichrysum*, *Craspedia*, and *Senecio* (Compos.).

2. The Elements of the Flora.

a. The Endemic element.

The endemic species of pteridophyta and spermophyta number 1322 and constitute 74 p. c. of the flora. If the above two classes be considered separately the specific endemism is respectively 26 p. c. and 79 p. c., while for the dicotyledons alone it rises to 85 p. c. The degree of endemism is by no means the same for all the species, but it differs greatly, the two extremes being, on the one hand, those species or groups of species only distantly related to any other either in New Zealand or elsewhere and those which bear a strong relationship to species of other countries where they may indeed possess vicarious representatives. For the purposes of this book five degrees of specific endemism are distinguished as follows: — 1. *Endemism of the first degree.* This includes those species which belong to endemic genera, subgenera, distinct sections of genera and even species or groups of such of extreme distinction. Examples are, — *Simplicia laxa*, *Scirpus* (*Desmoschoenus*) *frondosus*, *Carex* (section *Echinochlanae*) *cirrhosa*[2]), and *Veronica tetragona*[2]). 2. *Endemism of the second degree.* This includes species or groups of such at most very distantly related to foreign plants and fairly distinct from any other species or group. As above a group will have only one representative all the other members falling into Class 4. Examples are: — *Epilobium crassum*, *Veronica*

1) Doubtless much of the variation is due to hybridism of varieties (races which come "true" from seed).

2) Notwithstanding that *C. cirrhosa* is related to *C. rubicunda* and *C. Petriei* and *V. tetragona* to *V. Astoni*, *V. lycopodioides* &c. for these fall into Class 4 but the group to which they belong is represented as above.

dasyphylla, *Coprosma arborea*. 3. *Endemism of the third degree*. Here the species is generically related to some foreign genus but not closely to any foreign species of that genus. Examples are: — *Parsonsia heterophylla*, *Jovellana Sinclairii*. 4. *Endemism of the fourth degree*. Here come in all those species closely related to other New Zealand species, and they may be members of a group one of which is supposed to be more primitive and on that account placed in classes 1 or 2, as representative of the group. Examples are: — *Drimys colorata*, *Melicope simplex*, *Parsonsia capsularis*, *Veronica Hectori*. 5. *Endemism of the fifth degree*. Here not only may the species be related to some other indigenous one, but it must be closely related to some foreign species. Here, again, the species of a whole group may be so related, as in the case of *Carex secta* and its allies to *C. paniculata* of Europe, but only one species of the section, presumably the most primitive, goes into class 5, the others going into class 4. Examples are: *Carex Gaudichaudiana*, *Drapetes Dieffenbachii*, *Tetrachondra Hamiltonii*[1]). This arrangement of the endemic species into even five classes does not truly show the degree of endemism, since from my definitions, it is obvious that the classes would have to be further subdivided in order to approach the question of descent. Without however going more deeply into what is at best most problematical, the number of species in each class is as follows: — (Class 1) 120; (class 2) 292: (class 3) 68; (class 4) 772; (class 5) 70. *The members of class 4 forming 43 p. c.*[2]) *of the flora may be considered of comparatively recent origin, in some cases indeed their characters are hardly "fixed"*. The phytogeographical affinities of the members of classes 3 and 5 are: — (Class 3) Australian 30 species, Subantarctic-American 10, Malayan 9, Polynesian 8, Cosmopolitan 5, Eur.-Asian 5 and New Caledonian 1; (Class 5) Australian 34, Subantarctic South-American 13, Malayan 2, Polynesian 7, Cosmopolitan 2, Eur. Asian 5, Mediterranean 1, Norfolk Island 5, Tristan da Cunha 1.

An endemism of a higher grade[3]) is exhibited in the presence of 33 endemic genera. These are: — *Loxsoma* (Filices) distantly related to *Loxsomopsis* of Costarica and Ecuador; *Simplicia* (Gramin.) monotypic considered by HACKEL intermediate between *Sporobolus* (tropical and subtropical especially in America but only introduced in New Zealand) and *Agrostis* (see CHEESEMAN 1906 : 861); *Chrysobactron* (Liliac.), united by ENGLER (Pflanzenfamilien) to the South African *Bulbinella*; *Tupeia* (Loranthac.) a distinct monotype related both to the *Viscoideae* and the *Loranthoideae*; *Dactylanthus* (Balanophor.), a very distinct monotype, according to HOOKER "a most remarkable" genus; *Hectorella* (Caryophyl.) a monotype of somewhat doubtful affinity possibly related to the Ker-

1) The genus originally discovered by PETRIE was considered endemic and monotypic until SKOTTSBERG's interesting discovery of a closely related Patagonian species in 1909 which he has named *T. patagonica*.

2) Or 58 p. c. of the endemics.

3) Obviously the degree of endemism shown by the genera cited in this paragraph varies greatly, but the explanation as given for each genus should make its endemic position fairly clear.

guelan *Lyallia* (see EWART, Journ. Linn. Soc. 38; 1—3.) but placed by HOOKER and others in the *Portulacaceae*; *Pachycladon* (Crucif.), monotypic, according to HOOKER intermediate between the *Sisymbrieae* and the *Lepidineae*; *Notothlaspi* (Crucif.), contains 2 species, placed by PRANTL in the *Thelypodieae-Stanleyinae* next to *Pringlea* of Kerguelenland; *Ixerba* (Saxifragac.) monotypic, belongs to the section *Escallonioideae* and nearest to *Brexia* of Madagascar and the Seychelles; *Carpodetus* (Saxifragac.), monotypic, also belongs to the *Escallonioideae* and placed by ENGLER between the Australian-New Caledonian *Argophyllum* and the Lord Howe Island *Colmeiroa*; *Corallospartium* (Legum.) possibly monotypic, closely related to the almost endemic *Carmichaelia*; *Chordospartium* (Legum.), monotypic, confined so far as known to two valleys of the North-eastern district, nearest to *Corallospartium* but also possessing characters of *Carmichaelia* and the following genus; *Notospartium* (Legum.), contains at any rate two species, it differs from the above *Leguminosae* in its rather long, linear many-jointed pod and would be accorded generic rank by any systematist; *Alectryon* (*Sapindac.*), contains two closely-related species; *Entelea* (Tiliac.), monotypic, related to the South African *Sparmannia*; *Hoheria* (Malvac.), contains at least three species all of which are closely related, belongs to the *Malveae-Sidinae* and related to the indigenous genera *Plagianthus* and South American *Gaya*; *Tetrapathaea* (Passiflorac.) monotypic, by some united with *Passiflora*; *Stilbocarpa* (Araliac.), contains three species, two of which are confined to the Subantarctic district and the other to the Stewart and Fiord districts, somewhat closely related to *Aralia*, a Malayan, North American, East Asian and Australian genus; *Anisotome* (Umbell.) contains 19 species, closely related to the almost endemic *Aciphylla*, as also to *Ligusticum*; *Coxella* (Umbell.), monotypic and confined to the Chatham Islands, nearest to *Aciphylla*, but has also been referred to *Gingidium*, *Ligusticum* and *Angelica*; *Corokia* (Cornac.) consists of three species one of which is confined to the Chatham Islands; by HARMS the genus is placed between the Himalayan. — E. Asian *Helwingia* and *Cornus*, a genus wide-spread in the Northern Hemisphere; *Myosotidium* (Borrag.), monotypic, and confined to the Chatham Islands, a distinct genus belonging to the *Borraginoideae-Cynoglosseae*, its nearest ally appearing to be *Paracaryum* of Central Asia and the Mediterranean; *Teucridium* (Verbenac.), monotypic, related but not closely to the Himalayan-African *Holmskioldia*; *Siphonidium* (Scroph.), monotypic, closely related to *Euphrasia*, a common genus in New Zealand, but amply distinct; *Rhabdothamnus* (Gesneriac.), monotypic, forms with the New Caledonian *Coronanthera* and the Lord Howe *Negria* the small group *Cyrtandroideae-Coronanthereae-Coronantherinae*; *Alseuosmia* (Caprifoliac.) consists of four species, a distinct genus perhaps more closely related to *Lonicera* than to any other, but differing from all other *Caprifoliaceae* in its alternate leaves; *Colensoa* (Campanulac.), monotypic, closely related to *Pratia*, a common genus in New Zealand with which it is united by SCHÖNLAND; *Oreostylidium* (Stylidiac.). monotypic, related to the Australian *Stylidium*; *Pleurophyllum* (Compos.) contains 3 and perhaps 4 species, confined to the Subantarctic district, differs chiefly from the almost endemic *Celmisia* in habit and the heads being in racemes; *Haastia* (Compos.) contains four species, related to no indigenous genus but to the Madagascan *Psiadia*; *Raoulia*[1]) (Compos.) contains 20 species, related to the Australian *Helichrysum* and *Gnaphalium*, the cushion-species and some few others constitute the subgenus *Psychrophyton*; *Leucogenes* (Compos.) contains three species which are more closely related to *Psychrophyton* than to any other of the Gnaphaloid-*Compositae*; *Brachyglottis* (Compos.) contains at most two species which are closely allied to the shrubby section of the genus *Senecio*; *Traversia* (Compos.) monotypic, very closely related to *Senecio* and by BENTHAM and HOOKER united to that genus, but it differs in the rigid pappus, coriaceous involucral scales, and leaf-venation, as HOOKER pointed out, and is allied to the Juan Fernandez genera *Balbisia* and *Robinsonia*.

Endemism of a usually less marked character is shown by the following endemic divisions of genera numbering 15: — *Scirpus* (sect. *Desmoschoenus*); *Lepyrodia* (sect. *Sporodanthus*[2])), 1 species *L. Traversii*, the rest of the genus purely Australian; the group of six dwarf species of *Luzula*, *L. Colensoi*, *L. crenulata* &c.; *Cordyline* (sect. *Dracaenopsis*); *Knightia*, the type of the genus *K. excelsa* endemic, the remaining two species New Caledonian and form a sub-genus; *Beilschmiedia*, the two endemic species form HOOKER's genus *Nesodaphne*; *Acaena* (sect. *Microphyllae*); *Carmichaelia* (sect. *Huttonella*); *Epilobium*, the group *Dermatophyllae*; *Fuchsia* (sect. *Skinnera*); *Suttonia* (sub-gen. *Eusuttonia*); *Veronica* (section *Pygmaea*); *Veronica* (group including those of cupressoid-form from *V. Gilliesiana* to *V. cupressoides* according to CHEESEMAN 1906: 496—497); *Olearia insignis* since it differs, as CHEESEMAN points out, from the typical members of the genus, in the large broadly ovoid involucre, its bracts in very many series and the pappus of perfectly equal hairs (1906: 280); *Olearia* (*Shawia*) *Forsteri* and *coriacea* differs from other species of the genus in the heads *never* containing more than one floret.

If Lord Howe and Norfolk Islands were attached to the region, as they well might be, and leaving aside their special endemism, the endemic genera would be increased by *Phormium*, *Rhopalostylis* and *Carmichaelia*. With these additions, the total major and minor generic endemism rises to 51.

b. The Palaeozelandic element.

In considering the origin of the New Zealand flora, and indeed that of islands in general, the custom is to assume that the land was gradually peopled by plants from adjacent land-surfaces. But in the case of New Zealand, since the present dry land dates from mesozoic times; and, that long before the angiosperms had appeared on any part of the earth, its area, then quite

1) The Tasmanian species formerly referred to this genus have been put by BEAUVERD into his new genus *Ewartia*.

2) In my revision in 1920 of the proofs of this book, from p. 208 onwards, I have restored MUELLER's genus *Sporodanthus*, so it should properly come in the preceding paragraph.

extensive, was occupied by similar plants to the world at large, then, if there be anything in evolution, we must conclude that there is no reason why certain genera, now more or less wide-spread, should not be of New Zealand origin. In other words, it seems right to consider that *tertiary New Zealand possessed a flora part of which had originated on its own soil*, and that *there exists to-day an ancient New Zealand element* just as there does an Australian, Malayan or South American. Such an element was assumed by Engler, and is formed a portion of his palaeoceanic element. To this assumed autochthonic tertiary element I am giving the name "*palaeozelandic*". As to what genera should be included is largely a matter of conjecture. Certainly, the fact of endemism, at the present time, does not stamp a genus as palaeozelandic any more than does the occurrence of a common New Zealand genus in Australia, Malaya or even South America debar it from being so considered. Thus CHEESEMAN (1909:466) is of opinion that *Sophora tetraptera* and *Veronica elliptica* migrated from New Zealand to South America and not *vice versa*, as is generally believed. To go a little further, it seems not unlikely that various New Zealand plants, e. g., — *Chrysobactron*, *Stilbocarpa*, *Aciphylla*, *Celmisia* &c. are quite as much "Antarctic" as even *Nothofagus* and *Donatia*.

The following are possibly palaeozelandic[1]): — *Dacrydium*, *Podocarpus* (*Dacrycarpus* and *Stachycarpus*), *Phyllocladus*, *Carex* (*Echinoclaenae*), *Deschampsia* (group with awn absent or terminal and very short), *Astelia*, *Chrysobactron*, *Hectorella*, *Pachycladon*, *Carmichaelia*, *Notospartium*, *Sophora* (*Edwardsia*), *Gunnera* (*Milligania*), *Stilbocarpa*, *Nothopanax*, *Pseudopanax*, *Aciphylla*, *Anisotome*, *Coxella*, *Angelica* (the endemic group), *Corokia*, *Archeria*, *Dracophyllum*, *Gentiana* (*Antarctophila*), *Myosotidium*, *Myosotis* (*Exarrhena*), *Veronica-Hebe*, *Veronica-Pygmaea*, *Ourisia*, *Siphonidium*, *Coprosma*, *Oreostylidium*, *Plantago* (*Plantaginella*), *Lagenophora*, *Pleurophyllum*, *Celmisia*, *Haastia*, *Cotula* (*Leptinella*), *Raoulia* and *Leucogenes*.

c. *The Australian element.*

1. Genera &c.

The following 36 genera or subdivisions of such are confined to New Zealand and Australia: — *Althenia* [*Lepilaena*] (Potam.) 2 Aus., 1 N. Z., 1 common to both; *Microlaena* (Gramin.) 2 Aus., 4 N. Z., 1 common to both; *Echinopogon* (Gramin.) monotypic; *Amphibromus* (Gramin.) 1 Aus., 1 N. Z.; *Rhipogonum* (Lil.) 4 Aus., 1 N. Z.; *Herpolirion* (Lil.) monotypic, the sp. of subantarctic appearance; *Orthoceras* (Orchid.) monotypic; *Caleana* (Orchid.) 3 Aus., 1 common to both; *Cyrtostylis* (Orchid.) 1 Aus., 1 N.Z.; *Calochilus* (Orchid.) 1 Aus., 2 common to both; *Caladenia* (Orchid.) 27 Aus., 3 N. Z.; *Chiloglottis* (Orchid.) 5 Aus., 1 N. Z.; *Adenochilus* (Orchid.) 1 Aus., 1 N. Z.; *Townsonia* (Orchid.) 1 Aus., 1 N. Z.; *Persoonia* (Proteac.) 59 Aus., 1 N. Z.; *Fusanus* (Santal.) 4 Aus., 1 N. Z.; *Poranthera* (Euphorb.) 4 Aus., 1 N. Z., 1 common to both; *Rhagodia* (Chenopod.) 10 Aus., 1 common to

1) See also SKOTTSBERG regarding his "Old Antarctic Element" in Plant World, 18 (1915): 138.

both; *Quintinia* (Saxifrag.) 3 Aus., 2 N. Z.; *Ackama* (Saxifrag.) 1 Aus., 1 N. Z.; *Swainsona* (Legum.) 29 Aus., 1 N. Z.; *Phebalium* (Rutac.) 27 Aus., 1 N. Z.; *Plagianthus* (Malvac.) 9 Aus., 3 N. Z., *Gunnera* [*Milligania*] (Halorrhag.) 9 N. Z., 1 common to both; *Actinotus* (Umbel.) 9 Aus., 1 common to both; *Aciphylla* (Umbel.) 2 Aus., 25 N. Z.; *Pernettya* [*Porandra*] (Ericac.) 1 Aus., 1 N. Z.; *Pentachondra* (Epacrid.) 4 Aus., 1 common to both; *Epacris* (Epacrid.) about 23 Aus., 2 N. Z.; *Archeria* (Epacrid.) 3 Aus., 2 N. Z.; *Logania* (Loganiac.) 55 Aus., 1 N. Z.; *Liparophyllum* (Gentian.) monotypic and subantarctic in character; *Mentha* [*Eriodontes*] (Labiat.) all Aus. except 1 N. Z.; *Isotoma* (Campan.) 8 Aus., 1 common to both; *Forstera* (Stylid.) 1 Aus., 3 N. Z., all of subantarctic type; *Celmisia* (Compos.) 55 N. Z., 1 common to both; *Craspedia* (Compos.) about 6 N. Z. and 1 or 2 Aus. said to be identical with N. Z. spp.

Almost in the same class as the above are the genera which extend also to Norfolk or Lord Howe Islands and even New Caledonia; such are: — *Dichelachne* (Gram.); *Pterostylis*, *Acianthus* and *Lyperanthus* (Orchid.); *Pennantia* (Icacinac.); *Pomaderris* (Rhamnac.); *Hymenanthera* (Violac.) and *Olearia* (Compos.), 1 species of this large genus extends to Howe, the remainder are Aus. or N. Z. all the latter being endemic and, to some degree polymorphic.

The Subantarctic genera[1]) are as follows; they occupy, with but few exceptions, the subalpine belt in Eastern Australia and Tasmania, but in New Zealand many occur in the lowlands: — *Carpha* (Cyperac.); *Gaimardia* (Centrolep.); *Libertia* (Irid.); *Nothofagus* (Fagac.); *Colobanthus* (Caryophyl.); *Caltha* [sect. *Psychophila*] (Ranunc.); *Drimys* (Magnol.), also extends to New Caledonia, Malaya and New Guinea; *Drosera* [sect. *Psychophila*] (Droserac.); *Acaena* (Rosac.); *Discaria* (Rhamnac.); *Aristotelia* (Elaeocarp.), also 1 species in New Hebrides; *Drapetes* (Thymelaeac.), also 1 Borneo and 1 New Guinea; *Oreomyrrhis* (Umbel.), extends along the Andes from Chile to Mexico; *Crantzia* (Umbel.), also North America; *Schizeilema* (Umbel.); *Gentiana* [*Antarctophila*] (Gentian.); *Veronica* [*Hebe*] (Scroph.); *Ourisia* (Scroph.); *Selliera* (Gooden.); *Donatia* (Stylid.) and *Abrotanella* (Compos.).

Speaking of the New Zealand genera and families as a whole, 300 of the former (78 p. c.) are also found in Australia and, of the latter, all except the *Chloranthaceae*, *Corynocarpaceae*, *Tetrachondraceae* and *Coriariaceae*.

2. Species.

Leaving on one side the cosmopolitan element, the number of species common[2]) to New Zealand and Australia is 268. These may be arranged into

1) i. e. genera common to Aus. N. Z. and Subant. S. America, some of which, however have been already classed as palaeozelandic. Also add *Oreobolus* and *Plantago (Plantaginella)*.

2) As the two floras become better known, the tendency is to break up so-called identical species into two or more vicarious species. It is highly probable that many forms now supposed to be identical are distinct and that in some cases there is on aggregate species with distinct New Zealand and Australian representatives, e. g., — *Celmisia longifolia*, *Myosotis australis*, *Danthonia semiannularis* and many others.

the following principal classes: — 1. *Species of Australian origin.* 2. *Species of New Zealand origin.* 3. *with an equal claim to be considered either New Zealand or Australian.* 4. *Malayan.* 5. *Subantarctic.*

Taking the pteridophyta, the total number of species common to the two is 77 (48 p. c.) which arranged according to the above classes give, — 1. 2 species; 2. 7 of which 6 are of subantarctic character; 3. 5; 4. 50 or 65 p. c.; 5. 10; and there is also *Todaea barbara*, occurring in South Africa, 1 European species and 1 with a vicarious Northern representative. The monocotyledons number 91 (23 p. c.) and fall into 1. 34 species; 2. 13 of which 10 are of subantarctic character; 3. 15; 4. 9; 5. 4; and there are also 6 belonging to the temperate Northern hemisphere, 8 with vicarious representatives in the latter, 1 almost cosmopolitan and 1 occurring also in South Africa and St. Helena. In addition, 6 species have vicarious representatives in Australia. Coming finally to the dicotyledons the total is 100 and the percentage drops to 9 p. c. Arranged as above the figures are, — 1. 33 species; 2. 22, of which 13 are of subantarctic character; 3. 16; 4. 6; 5. 17; and in addition 2 are North temperate, 2 are represented by North temperate vicarious species, and 2 occur on Tristan da Cunha, 1 of which is also South African.

The statistics and details as given above, greatly exaggerate the importance of the Australian element and also the floristic relations of the two floras. A considerable part of the species common to both, occur only on the mountains of Tasmania and the higher Australian Alps. Many families and genera, characteristically Australian, are either absent or very poorly represented, e. g., — *Eucalyptus*, *Callistemon*, *Melaleuca* and other *Myrtaceae*, *Proteaceae* of which there are but 2 species in New Zealand, *Dilleniaceae*, *Tremandraceae*, genera of *Leguminosae* such as *Acacia* and *Pultenaea*, the important family *Rutaceae* with the genera *Boronia* and *Eriostemon*, *Casuarina*, various monocotyledonous genera &c. *It is hardly going too far to say that it would be possible for one to have an excellent acquaintance with the botany of Eastern Australia and yet to be acquainted with very few indeed of the species which extend to New Zealand.*

d. The Subantarctic element.

It is the presence of a well-defined element common to New Zealand, Eastern Australia and Tasmania, subantarctic South America, and the extra-New Zealand subantarctic Islands that has given rise to endless speculations as to its origin.

1. Genera [1]).

The following genera, 129 in number, are common to Subantarctic South America &c. New Zealand and in the majority of cases Australia [2]) also: — *Hymenophyllum*, *Trichomanes*, *Dicksonia*, *Cheilanthes*, *Pellaea*, *Cys-*

1) The reader should consult the volume of this series on Chile (REICHE 1907: pp. 299—302) where more details are given than there is space for here; also HEMSLEY, 1885: pp. 52—58.

2) The mark † attached to a genus or species means absent in Australia.

topteris, *Pteridium*, *Pteris*, *Blechnum*, *Asplenium*, *Polystichum*, *Polypodium*, *Notochlaena*, *Gymnogramme*, *Gleichenia*, *Schizaea*, *Ophioglossum*, *Botrychium* (Filices.); *Azolla* (Salviniac.); *Isoetes* (Isoetac.); *Lycopodium* (Lycopod.); *Dacrydium*, *Podocarpus* (Taxac.); *Libocedrus* (Pinac.); *Triglochin* (Scheuchz.); *Potamogeton* (Potamoget.); *Hierochloe*, *Agrostis*, *Calamagrostis*, *Deschampsia*, *Trisetum*, *Danthonia*, *Koeleria*, *Poa*, *Festuca*, *Bromus* (Gramin.); *Schoenus*, *Cladium* (*Vincentia*†) 1 species Juan Fernandez, *Oreobolus*, *Uncinia*, *Carex* (Cyperac.); *Leptocarpus* (Restion.); *Gaimardia* (Centrolep.); *Rostkovia*†, *Marsippospermum*†, *Juncus*, *Luzula* (Junc.); *Enargea*†, *Astelia* (Liliac.); *Libertia* (Iridac.); *Spiranthes* (Orchid.); *Nothofagus* (Fagac.); *Urtica* (Urticac.); *Phrygilanthus* (Loranth.); *Knightia* (Proteac.) reported as fossil in Seymour Isld. close to Grahamland, *Polygonum*, *Rumex*, *Muehlenbeckia* (Polygonac.); *Chenopodium*, *Atriplex*, *Suaeda*, *Salicornia* (Chenopod.); *Mesembryanthemum*, *Tetragonia* (Aizoac.); *Montia* (Portulac.); *Stellaria*, *Colobanthus*, *Spergularia*, *Scleranthus* (Caryoph.); *Ranunculus*, *Myosurus*, *Caltha* [*Psychrophila*] (Ranun.); *Drimys* (Magnoliaceae-Illicieae); *Laurelia* (Monimiac.); *Cardamine*, *Sisymbrium*, *Lepidium* (Crucif.); *Drosera* [*Psychophila*] (Droserac.); *Crassula* [*Tillaea*] (Crassulac.); *Rubus*, *Geum*, *Acaena* (Rosac.); *Sophora*† (Legum.); *Geranium* (Geran.); *Oxalis* (Oxalidac.); *Linum* (Linac.); *Callitriche* (Callitrich.); *Coriaria*† (Coriariac.); *Discaria* (Rhamnac.); *Aristotelia* (Elaeocarp.-Aristotel.); *Hypericum* (Guttif.); *Drapetes* (Thymel.); *Myrtus*, *Eugenia* (Myrtac.); *Viola* (Violac.); *Epilobium*, *Fuchsia*† (Onagrac.); *Halorrhagis*, *Gunnera* (Halorrhag.); *Pseudopanax*† (Araliac.); *Azorella*†, *Schizeilema*, *Apium*, *Crantzia*, *Oreomyrrhis* (Umbell.); *Griselinia*† (Cornac.); *Gaultheria*, *Pernettya* (Ericac.); *Samolus* (Primulac.), *Gentiana* (Gentian.); *Calystegia* (Convolv.); *Myosotis* (Borrag.); *Tetrachondra*†, *Scutellaria* (Labiat.); *Jovellana*†, *Limosella*, *Veronica*, *Ourisia*, *Euphrasia* (Scroph.); *Utricularia* (Lentibul.); *Plantago* (Plantag.); *Coprosma*, Juan Fernandez, *Nertera*, *Galium* (Rubiac.); *Pratia* (Campan.); *Selliera* (Gooden.); *Phyllachne*†, *Donatia* (Stylid.); *Lagenophora*, *Gnaphalium*, *Cotula*, *Abrotanella*, *Senecio*, *Taraxacum* (Compos.).

2. Species.

More important than the generic relationship is the fact that there are at least 66 species identical, or almost so, in the Subantarctic and New Zealand floras and that these have remained unchanged through long periods, isolation notwithstanding. Further there are 32 vicarious species.

d) Species common to New Zealand and Subantarctic South America &c. *Hymenophyllum rarum*, *H. ferrugineum* (restricted to Juan Fernandez, Chile and N. Z., closely related to *H. aeruginosum* of Tristan da Cunha), *H. tunbridgense*, *H. peltatum*, *Cystopteris fragilis*, *Pteridium esculentum*, *Histiopteris incisa*, *Blechnum penna marina*, *B. capense*, *Asplenium obtusatum*, *Polystichum vestitum*, *P. adiantiforme*, *Polypodium Billardieri*, *Schizaea fistulosa* var. *australis*, *Botrychium lunaria* (Filic.); *Hierochloe redolens*[1]), *Agrostis magellanica*, *Trisetum*

1) According to Hackel and Pilger the South American species is the very closely-related *H. magellanica* Lam.

subspicatum, *Festuca erecta* (Gramin.); *Scirpus aucklandicus* (Amsterdam Island), *S. cernuus*, *S. nodosus*, *Uncinia macrolepis*, *U. compacta*, *Carex Darwinii* var. *urolepis*, *C. trifida*, *C. Oederi* var. *catarractae*, *Carex pumila* (Cyperac.); *Rostkovia magellanica*, *Juncus planifolius*, *J. scheuchzerioides*? (Junc.); *Mesembryanthemum aequilaterale*, *Tetragonia expansa* (Aizoac.); *Montia fontana* (Portulac.); *Colobanthus quitensis* (Caryophyl.); *Myosurus aristatus*, *Ranunculus acaulis*, *R. crassipes* (Ranunc.); *Cardamine heterophylla*, *C. corymbosa*, *C. glacialis* (Crucif.); *Crassula moschata* (Crassulac.); *Geum parviflorum* (perhaps not truly identical), *Acaena adscendens* (Rosac.); *Sophora tetraptera* (the Auckland and Chatham Island plant seem to differ but little from the South American and show at best a hint of the divaricating juvenile form) (Legum.); *Oxalis magellanica*[1]) (Oxalidac.); *Callitriche antarctica* (Callitrich.); *Coriaria ruscifolia*, *C. thymifolia* (I have grave doubts as to the identity of these spp. with those bearing the same names in New Zealand floristic writings but in any case both in New Zealand are aggregates) (Coriariac.); *Halorrhagis erecta* (Juan Fernandez), *Myriophyllum elatinoides* (Halorrhag.), *Apium prostatum*, *Hydrocotyle americana*, *Oreomyrrhis andicola* (possibly the N. Z. forms of this aggregate, vars. *Colensoi*, *rigida*, *ramosa* &c. are distinct from any in South America), *Crantzia lineata*, *Azorella Selago* (in N. Z. only in Macquarie district) (Umbell.); *Samolus repens* (Primulac.), *Calystegia Soldanella*, *C. tuguriorum*, *Dichondra repens* (Convol.); *Gratiola peruviaua*, *Limosella tenuifolia*, *Veronica elliptica* (I cannot tell how near the South American plant comes to one or other of the many forms of the New Zealand aggregate species) (Scroph.); *Nertera depressa* (Rubiac.), *Selliera radicans* (Gooden.), *Cotula plumosa*, *C. coronopifolia*, *Taraxacum magellanicum*.

Equally as interesting as the identical species are the vicarious. These are[2]): —

Azolla rubra — *A. filiculoides* (Salvin.); *Lycopodium fastigiatum* — *L. magellanicum* (Lycopod.); *Koeleria superba* — *K. Bergii*, *Poa litorosa* — *P. novarae* (St. Paul and New Amsterdam); *P. foliosa* — *P. Cookii* and *P. flabellata*, *Festuca novae-zelandiae* — *F. magellanica* (Gramin.); *Schoenus pauciflorus* — *S. antarcticus*; *Oreobolus pectinatus* — *O. obtusangulus*, *Carpha alpina* — *C. schoenoides*, *Carex pseudocyperus* var. *fascicularis* — var. *Haenkeana* (Cyperac.); *Gaimardia setacea* — *G. australis* (Centrolep.); *Marsippospermum gracile* — *M. Reichii*, *Luzula campestris* var. *crinita* — *L. alopecurus*, *L. racemosa* var. *Traversii* — *L. racemosa* (Junc.); *Astelia linearis* — *A. pumila*, *Enargea parviflora* — *E. marginata*[3]) (Liliac.); *Nothofagus Menziesii* — *N. betuloides* (Fagac.); *Rumex neglectus* — *R. cuneifolius* (Polygonac.); *Colobanthus muscoides* (confined to the subantarc. prov.) — *C. kerguelensis*, *C.* sp. — *C. subulatus* (Caryoph.); *Caltha novaezelandiae* — *Caltha sagittata* (Ranunc.);

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1) Skottsberg considers that possibly this is not identical with the N. Z. plant which he refers to *O. lactea* Hook. Plant World, 18 (1915): 135.

2) The name coming first of the pair is the N. Z. species.

3) I am indebted to Dr. Skottsberg for pointing out to me the differences between the N. Z. and Fuegian plants.

Laurelia novae-zelandiae — *L. aromatica*, *L. serrata* (the genus confined to southern S. America and N. Z., but also reported as fossil on Seymour Island, Monimiac.); *Drosera stenopetala* — *D. uniflora* (Droserac.); *Geranium sessiliflorum* var. *glabrum* — *G. sessiliflorum* (Geran.); *Discaria toumatou* — *D. discolor* (Rhamnac.); *Drapetes Dieffenbachii* — *D. muscosus* (Thymel.); *Epilobium pedunculare* — the same or some closely related form (Onagrac.); *Tetrachondra Hamiltonii* — *T. patagonica* (Labiatae); *Euphrasia zealandica* — *E. antarctica* (Scroph.); *Plantago Brownii* — *P. barbata* (Plantag.); *Pratia angulata* — *P. repens* (Campan.); *Donatia novae-zelandiae* — *D. fascicularis* (Stylid.); *Lagenophora pumila* — *L. Commersonii*, *Abrotanella muscosa* — *A. emarginata* (Compos.)

e. The Palaeotropic element.

Under this term come the Malayan, Australian-Malayan, Melanesian and Polynesian elements of the flora.

1. Families and genera.

The following are the principal families and genera: — (Families) *Burmanniaceae*, *Pandanaceae*, *Palmae*, *Chloranthaceae*, *Moraceae*, *Loranthaceae*, *Santalaceae*, *Balanophoraceae*, *Nyctaginaceae*, *Monimiaceae*, *Lauraceae*, *Meliaceae*, *Euphorbiaceae*, *Icacinaceae*, *Corynocarpaceae*, *Elaeocarpaceae*, *Tiliaceae*, *Passifloraceae*, *Myrtaceae*, *Araliaceae*, *Myrsinaceae*, *Loganiaceae*, *Apocynaceae*, *Convolvulaceae*, *Verbenaceae*, *Gesneriaceae*, *Rubiaceae*, *Cucurbitaceae*; (Genera) *Hymenophyllum*, *Trichomanes*, *Cyathea*, *Hemitelia*, *Alsophila*, *Dicksonia*, *Davallia*, *Leptolepia*, *Lindsaya*, *Adiantum*, *Cheilanthes*, *Pellaea*, *Paesia*, *Pteris*, *Doodia*, *Diplazium*, *Athyrium*, *Nephrolepis*, *Gymnogramme*, *Gleichenia*, *Lygodium*, *Marattia* (Filic.); *Tmesipteris*, *Psilotum* (Lycopod.); *Agathis* (Pinac.); *Freycinetia* (Pandan.); *Imperata*, *Paspalum*, *Isachne*, *Panicum*, *Oplismenus*, *Cenchrus*, *Alopecurus*, *Eleusine* (Gramin.); *Mariscus*, *Fimbristylis*, *Cladium* (Cyperac.); *Rhopalostylis* (Palm.); *Cordyline* (Lil.); *Dendrobium*, *Bulbophyllum*, *Earina*, *Sarcochilus* (Orchid.); *Macropiper*, *Peperomia* (Piperac.); *Ascarina* (Chloranth.); *Paratrophis* (Morac.); *Elatostema*, *Boehmeria* (Urtic.); *Elytranthe*, *Loranthus*, *Korthalsella* (Loranth.); *Euphorbia*, *Homalanthus* (Euphorb.); *Pisonia* (Nyctag.); *Hedycarya* (Monimiac.); *Litsaea*, *Cassytha* (Laurac.), *Weinmannia* (Cunon.); *Pittosporum* (Pittosporac.); *Canavalia* (Legum.); *Melicope* (Rutac.); *Dysoxylum* (Sapind.); *Corynocarpus* (Corynocarp.); *Elaeocarpus* (Elaeocarp.); *Hibiscus* (Malvac.); *Metrosideros*, *Eugenia* (Myrtac.); *Meryta*, *Schefflera* (Araliac.); *Sideroxylon* (Sapotac.); *Geniostoma* (Loganiac.); *Parsonsia* (Apocynac.); *Ipomaea* (Convol.); *Myoporum* (Myoporac.); *Vitex*, *Avicennia* (Verben.); *Solanum* (Solan.); *Sicyos* (Cucurb.); *Scaevola* (Gooden.); *Siegesbeckia*, *Bidens* (Compos.).

For the most part, the species of these genera are endemic, but nevertheless they form a distinct element of the flora, which is in large part restricted to the warmer and frostless parts of the region, comparatively few species gaining the subalpine belt or, in the S., leaving the coast-line.

2. Species.

If the numerous palaeotropical pteridophyta, the fairly large widely-distributed tropical and subtropical element and the few Norfolk-Howe species be here left out of consideration, the few remaining species shared by New Zealand with other palaeotropic floras are, — *Podocarpus ferrugineus* (Taxac.), New Caledonia only; *Cenchrus calyculatus* (Gramin.), but to Kermadecs only; *Cladium articulatum*, *C. glomeratum*, *Gahnia gahniaeformis* (Cyperac.); *Macropiper excelsum* (Piperac.); *Melicytus ramiflorus* (Violac.); *Metrosideros villosa* (Myrtac.), but Kermadec only.

f. The Cosmopolitan element.

Here the term "Cosmopolitan" is used with a rather wide significance, and all those species are included that have a considerable range in either temperate or warm climates. Some, especially those of warm countries, are ecologically akin to weeds, so that it is difficult, or impossible to decide, whether their present distribution has come about by "natural" means, or whether, also, some of those found in New Zealand are truly indigenous. Even regarding the well-known floras of European lands, exposed as these have been for long periods to the influence of man, it must be a matter of great uncertainty as to what species are actually indigenous, and, it may well be, that many species, concerning the nativity of which no question has ever been raised, have originated far from what is now the centre of their greatest distribution.

The most important section, from the phytogeographical standpoint, consists of those species supposed to belong without question to the Northern hemisphere, a matter however rather taken for granted than proved. These species fall into the two classes of those in which the northern and southern forms are almost identical and those in which a species or group of species in the N. has one or more vicarious southern representatives.

The following are important examples: — *(Identical species) Hymenophyllum tunbridgense*, *H. peltatum*, *Cystopteris fragilis*[1]), *Asplenium Trichomanes*, *Botrychium lunaria* (Filic.); *Lycopodium Selago* (Lycopod.); *Ruppia maritima* (Potam.); *Trisetum subspicatum* (Gramin.); *Carex stellulata*, *C. lagopina*, *C. diandra*, *C. pseudocyperus* (Cyper.); *Montia fontana* (Portulac.); *Callitriche verna* (Callitrich.); *Calystegia Soldanella* (Convolv.);, *(Vicarious species) Pteridium aquilinum* — *P. esculentum*; *Ophioglossum lusitanicum* — *O. coriaceum*, *O. vulgatum* — *O. pedunculosum*, *Botrychium ternatum* — *B. australe* (Filic.); *Lycopodium clavatum* — *L. fastigiatum* (Lycop.); *Agrostis canina* — *A. Dyeri* &c., *Deschampsia caespitosa* — var. *macrantha*, *Koeleria gracilis* — *K. superba* &c., *Festuca ovina* — *F. novae-zelandiae* &c. (Gramin.); *Carex pyrenaica* — var. *cephalotes*, *C. paniculata* — *C. appressa* and its allies, *C. Goodenoughii (vulgaris)* — *C. Gaudichaudiana* and its allies, *C. Oederi* — var. *catarractae* (Cyperac.); *Juncus effusus* — a series of forms some endemic., *J. maritimus*

1) The N. Z. species, *C. novae-zelandiae* J. B. Armstg. is probably distinct from *C. fragilis*.

— var. *australiensis*, *Luzula campestris* — vars. *Petriana*, *picta*, *migrata* &c., a remarkable series (Junc.); *Chenopodium glaucum* — var. *ambiguum* (Chenopod.); *Cardamine hirsuta* — *C. heterophylla* (Crucif.); *Potentilla anserina* — var. *anserinoides* (Rosac.); *Geranium dissectum* — *G. pilosum* (Geran.); *Epilobium tetragonum* — *E. Billardierianum* (Onagrac.); *Apium graveolens* — *A. prostratum* (Umbel.); *Taraxacum officinale* — *T. magellanicum* (Compos.).

Carex stellulata, cited above, a common species in the N., is an interesting case, since it is confined in the Southern hemisphere to New Zealand and Australia. More remarkable still is the fact that *C. lagopina*, a species of arctic and alpine Eur-Asia and N. America, in the S. is restricted to altitudes of 1200 m and upwards in the South Island of New Zealand and according to CHEESEMAN is undoubtedly indigenous (1906 : 818).

g. Lord Howe and Norfolk Islands.

The fairly close floristic relationship of the above islands to New Zealand has already been noted when dealing with the Kermadec Group and certain statistics given. Here only a few special details are necessary. The following otherwise endemic New Zealand species extend to Lord Howe Island: — *Gahnia xanthocarpa*, *Uncinia filiformis*[1]) and *Hymenanthera novae-zelandiae* (according to W. R. OLIVER). *Coprosma Baueri*[2]) occurs in Howe, Norfolk and New Zealand. More important however is the occurrence of *Carmichaelia* and *Sophora tetraptera*. The other New Zealand species with one or two exceptions are likewise Australian and this also applies to Norfolk Island.

The special New Zealand-Norfolk Island species are: — *Phormium tenax*, *Muehlenbeckia australis* and *Olea apetala*. There are also the following vicarious species: — *Rhopalostylis Baueri* — *R. sapida*, *R. Cheesemanii*, *Pennantia Endlicheri* — *P. corymbosa*; *Hymenanthera latifolia* — *H. novae-zelandiae*; *Sideroxylon costatum* — *S. novo-zelandicum*. The most important features are the presence of the genera *Phormium* and *Rhopalostylis*.

3. General Conclusions.

In order to pave the way for the concluding part of this work it is advisable to state briefly some conclusions derived from the details given in this chapter.

The flora of New Zealand, notwithstanding its strong endemism, possesses two very distinct elements not floristic only but ecological. The first, and, as I believe, the more primitive, is not one simple floristic entity, but consists of a combination of the palaeozelandic and subantarctic elements of the flora,

1) But as var. *debilior* (Muell.) W. R. Oliver according to OLIVER, but KÜKENTHAL refers the plant to *U. riparia R. Br.*, an Australian-New Zealand species.

2) W. R. OLIVER (T. N. Z. I., (1917): 153) restricts *C. Baueri* to Norfolk Island and separates the Lord Howe plant under the name *C. prisca* and restores Hookers name *retusa* for the N. Z. plant. To the same group belong *C. petiolata* (Kermadecs) and *C. chathamica* (Chathams).

now difficult to disentangle. They have this one property in common, the power, for the most part to endure a fair amount of cold.[1]) In other words, the element is a temperate one.

The second element, also largely endemic, consists of descendents of an ancient palaeotropic stock, so ancient indeed that endemic genera have been developed (*Rhabdothamnus*, *Ixerba*, *Alectryon* &c.), as well as many distinct endemic species.

Yet notwithstanding this great age of the members, and their long isolation far from the tropics, but few have become really fitted to the present average climate of New Zealand, in fact the majority can tolerate very little frost. For the most part, the species of this class are confined to the lowlands, and in the S. some are only found near the coast. This element, in fact, is eminently subtropical; so that the present-day climate is one to which it is not perfectly attuned[2]). Should a change of climate occur, then with increase of temperature the palaeotropic element would advance southwards and the palaeozelandic-subantarctic retreat to the mountains, while, with increase of cold, the contrary would be the case. The isolated colonies of *Nothofagus fusca,* in the North Auckland district, point to such a change of climate, while the presence of the tree-fern *Hemitelia Smithii* in the Lord Auckland's district suggests a warmer period. But apart from speculations, the non-toleration of frost by so many New Zealand species is good evidence that there has either been a considerable northern land-extension during the glacial period or else that such did not owe its origin even, in part, to increase of cold.

It has been shown that while there is a considerable Australian element, it is made up largely of Subantarctic and Palaeotropic species, while the true Australian element does not play a conspicuous part in the vegetation. Especially is the absence of characteristic Australian genera noteworthy, e. g., — *Eucalyptus*, *Acacia* &c., although virtually all the Tasmanian species are not only quite hardy in the warmer parts of New Zealand, but some can spread spontaneously. Bearing these facts in mind, the possibility of direct land-connection with Eastern-Australia except at a remote period cannot be entertained.

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1) Nevertheless they are, generally speaking, quite unable to tolerate cold equivalent to that of Central Europe.

2) For example *Cordyline australis* is killed during a specially severe winter.

Part IV.

The History of the Flora from the Jurassic Period to the Present Time.

1. General.

The origin and subsequent history of the New Zealand flora is, in great measure, a matter of speculation merely, for the material on which conclusions are to be based is, in no small degree, unsatisfactory and insufficient. In the first place, the all-important statistics as to floristic elements are, of necessity, drawn from existing floras, although the composition of these must be very different from those of the same areas in Tertiary times. It is also assumed, in phytogeographical writings generally, that the absence of a species from any area means that the species in question was never there, a supposition quite at variance with both present happenings and fossil records. Again, although a certain genus has its richest development in some particular area, it does not follow that such would be the original centre of its distribution. No phytogeographer, for example, would admit New Zealand as the birth-place of *Veronica*, its 100 or more species notwithstanding, and their innumerable varieties. On the other hand, none would deny *Celmisia* a New Zealand origin, but is bears the appearance of a genus in process of rapid change with many recently-evolved species, as yet hardly differentiated; indeed *Veronica* and *Celmisia* are in much the same condition from the evolutionary standpoint[1]).

The matter of ancient land-connections, where there are now profound ocean-depths, is the burning question in New Zealand biogeography. But, here again, the ground is most insecure, and one can only say that the question of great changes in the relations of land and water is one on which there is about equal evidence for and against. Geology can make no definite pronouncement, and the matter, at present, rests solely on the facts of organic distribution and whether certain critical examples can be clearly explained without the assumption of "land-bridges". To some this biological evidence is all-conclusive, especially from the zoological standpoint; HEDLEY for instance (1899: 393) going so far as to ignore the testimony of ocean-depths and construct a hypothetical land-area on biological considerations alone[2]). Others, again will not allow land-connections at any price. With regard to plants,

1) They might equally well be considered either recent arrivals or ancient indigenous genera recently revivified through some great change of outer circumstances.

2) "The only safe method of reasoning is to eliminate the factor of the depth of intervening seas, since we cannot count the amount of past possible upheaval or depression and to rely on biological data alone".

it is generally assumed, that there is a possibility of their being conveyed by wind, or even birds, across wide stretches of ocean, especially in the case of sporiferous species. But even with these latter, the spores of a plant, inhabiting only a windless forest-interior, could never be the sport of the wind. The case of *Hymenophyllum ferrugineum* of Juan Fernandez, Chile and New Zealand is hard to explain on the supposition of wind-carriage and equally difficult is that of *H. Malingii*, an epiphyte, of quite local occurrence, on the trunks of certain *Taxaceae* or *Pinaceae* in New Zealand and Tasmania, but absent on neighbouring dicotylous trees. Were spores as readily carried by the wind, as is supposed, there should be no special fern-floras, which is not the case[1]); nor should the endemic *Polypodium novae-zealandiae* be confined to one portion of the North Island of New Zealand, since it ascends to the subalpine belt. Regarding the seed-plants, the important evidence already given concerning the distribution of alien species in New Zealand, equipped in every way for travel and ecesis, and their relation to the primeval vegetation, shows how exceedingly difficult it is for a plant to gain entrance into a virgin plant-formation.

Ecesis, rather than the possibility of bird-carriage &c. during long periods of time, is the great stumbling-block. Transoceanic dissemination may rightly be evoked as an explanation of the presence of Australian, Polynesian and even Northern species in the fact of migratory birds from the first two regions and Siberia. The carriage of seeds and even cryptozoic animals, on trees brought to the sea by flooded rivers, seems the most feasible method of travel for many species. The indehiscent seed-pod of *Sophora* might long preserve the seeds within undamaged by sea-water. Logs are carried from the main islands to the Chatham group; these islands and the Lord Auckland's have been colonized by various European birds blown from New Zealand; smoke from forest-fires on the mainland frequently gains the Chathams and, according to MARSHALL[2]), a storm of dust has reached New Zealand from Australia. All these facts, and others of a like kind could be cited, show how seeds could be *rapidly* conveyed over great distances, but, *between the arrival of seed or spore and its becoming a mature plant in a situation favourable, not only for its well-being, but for its increase, is altogether another matter.*

Granting that plants of all kinds can be transported over thousands of kilometres of ocean, a supposition taxing one's judgement to no small degree, there comes in the carriage of animals. Now with regard to various classes of such there is a striking Subantarctic affinity. The matter is gone into at considerable detail by HUTTON, CHILTON, BENHAM and others[3]); here only a few cases are noted. But first it must be pointed out, that although it might be possible, though extremely difficult, to suggest a plausible explanation for

1) CHRIST, Die Geographie der Farne 1910: 141 et seq.

2) Dust-storms in New Zealand. Nature LVIII (1903): 223.

3) See General Bibliography to the Subantarctic Islands of New Zealand, 11 (1909): 808 et seq. where many important publications dealing with southern bio-geography are cited.

every case on the supposition of ocean-transit, yet that such could apply to the organisms as a whole is a totally different matter.

Galaxias attenuata, a fresh-water fish, occurs in New Zealand, Tasmania, S. E. Australia, the Falklands and Subantarctic South America. *Notiodrilus*, a genus of earth-worms, is found in New Zealand including the Subantarctic province, Kerguelen, Marion Island, the Crozets, South Georgia, the Falklands, Subantarctic South America and South Africa. *Phraeodrilus*, another genus, is represented, according to BENHAM (1909: 254), by 3 or 4 New Zealand species and 6 others distributed on Kerguelen, the Crozets, the Falklands and Fuegia. A species of terrestial crustaceans, genus *Trichoniscus*, according to CHILTON (1909: 799), occurring in the Subantarctic province, is identical with a species of Fuegia, the Falklands and possibly with one of the Crozets. *Idotea lacustris*, a fresh-water Isopod, occurs in New Zealand, Campbell Island and Subantarctic America. A spider, *Pacificana Cockayni*, from Bounty Island (Subantarctic province) is related to genera from Tasmania and Cape Horn. A group of fresh-water *Crustacea*, including the New Zealand genus *Boeckella*, is represented in extra-New Zealand Subantarctic lands by closely allied genera, while the genus itself occurs in subalpine lakes of Tasmania. The beetle *Loxomerus* is purely Subantarctic[1]).

Just as the botanical evidence of the last chapter and the zoological, of which the above is altogether incomplete, make out a strong case for a Subantarctic or Antarctic "land-bridge", so does the great depth of the ocean to the S. and E. of the New Zealand continental shelf shake ones belief in the possibility of such connection. It is true that Captain DAVIES in Mawson's ship, the Aurora, discovered a small area of comparatively shallow water to the S. of Tasmania, but he likewise demonstrated the presence of very deep sea between Macquarie and Lord Auckland's Islands. Further, as seen from the geographical chapter, New Zealand is surrounded by a fairly shallow sea, which to E. W. and S. suddenly sinks to a profound depth. Obviously, this shallow sea denotes an ancient land-surface, but the sudden drop affords strong evidence that deep water has existed, as at present, for an extremely long period. On the other hand, there may have been a long-continued earth-movement to which the present ocean-depth is due. However, the matter is one of mere speculation, and in the light of our present knowledge only, a belief or disbelief in land-connection rests solely on the belief in the possibility or impossibility of the plants and animals having been able to cross the vast stretch of ocean by means of wind- or bird-carriage alone. The difficulty of believing in this lengthy transoceanic transit is so great that I must declare for the problematical "bridge", but this must have existed at a time antecedent to the advent of mammals on the connected area.

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1) From a study of the distribution of brachiopod faunas in Antarctic and subantarctic lands, J. A. THOMSON postulates land-connection or a relatively shallow sea between Australia, New-Zealand and Kerguelen Land, Antarctica and South America in the early Tertiary (Austral. Antarc. Exped., Scientif. Reps., Zool. and Bot., 4 (1918): 59).

Finally, ceme thso question of multiple origins. This is rarely seriously advocated at the present time, but, strange to say, in pre- Darwinian days, it was a common belief, though there was not a shred of evidence to show how such a phenomenon could take place. But in the present state of knowledge, there seems to me no reason, according to any accepted theory of evolution, and especially to the doctrine of mutation, why polygenesis should not take place occasionally. It would, of course, occur most frequently with regard to families and genera, and specific polygenesis would be a rare occurrence.

2. The History of the Flora.

During the mesozoic period, according to MARSHALL (1912: 35), New Zealand was the "shore-line of a continent that stretched far to the westward and probably united New Zealand with Australia".

From the fossils that have been collected at Waikato Heads, Clent Hills and Mt. Potts (Canterbury) and Southland, it is evident that a rich vegetation clothed New Zealand in Jurassic times consisting of ferns, *Equisetaceae*, *Pteridosperms* and *Coniferae*, petrified remains of a forest of the latter still persisting at Curio Bay. According to ARBER[1]), *Glossopteris* was absent, so that New Zealand was not a portion of "Gondwanaland", but it was represented by a homaeomorph *Linguifolium Lillieanum*, a close relation of a Chilean species. Other Jurassic species are a species of *Baiera* allied a Swedish Rhaetic plant, *Taeniopteris Daintreei* (also Australian), *Chiropteris lacerata*, *Cladophlebis australis*, *Palissya conferta* (Indian but also occurring in Graham Land), *Osmundites Gibbiana* and *O. Dunlopi*. Probably the climate was much warmer than at the present time.

At the close of the Trias-Jura period, the Mesozoic rocks were folded and a great rise together with an extension of the land took place. Such evolution processes, as were taking place in other parts of the world, would go on continuously and many New Zealand species &c. be evolved and exchanges take place with the neighbouring lands. How far Greater New Zealand extended in the early Tertiary, no one can say, but it most likely embraced New Caledonia in the N. and probably went much further. In the S., it would certainly reach Campbell Island and it may have gone far beyond. At this time, the palaeotropic element would people the N. while the S. perhaps considerably warmer than to-day would receive invaders from Subantarctic lands and, simultaneously many of the palaeozelandic genera come into being.

Remnants of this rich ancient flora occur in many localities, especially in Otago and Southland. The fossils have been studied by ETTINGHAUSEN, who refers some to various Northern genera which one would not expect in the Southern Hemisphere, especially Australasia, e. g. — *Myrica*, *Alnus*, *Quercus*,

1) A Preliminary Note on the Fossil Plants of the Mount Potts Beds, New Zealand, Collected by Mr. D. G. LILLIE, Biologist to Captain Scott's Antarctic Expedition in the "Terra Nova". Proc. R. S. 1913: 344.

Ulmus and *Acer*. He also records the Australian *Casuarina* and *Eucalyptus*. Mixed with these were plants referred to existing New Zealand genera or their representatives. Judging from the figures accompanying the descriptions, ETTINGHAUSEN's identifications, if accepted at all, must be received with the greatest doubt, indeed I do not think they are of any value. But were these genera present, then there must have been a universal temperate flora, a matter hardly conceivable in the fact of the tropical climate as a barrier. This tertiary fossil flora, however, is a fact, and it teaches us that many species and genera have passed away, just as the present species would have gone, in the future, or changed by natural means, had New Zealand remained a virgin land.

The great elevation was succeeded by an equally great depression in the Oligocene-Miocene, so that New Zealand became merely a series of small islands. This reduction of the land-surface must have brought about the extinction of many species, especially amongst the alpine plants, and plastic species, perhaps the sole survivors of large genera, would find a haven of refuge on rock-faces and other habitats unsuited for forest-plants. It follows then that the primitive Subantarctic element would be decimated and that the present species or genera are a mere fraction of the original extensive company. As for the lowland forest species they would not suffer nearly so much, for it is surprising how great a plant-population can thrive on a small island, such as the Little Barrier, where there are, at the present time most of the forest-plants of Northern Auckland.

During the Pliocene elevation again took place and extended far into the Pleistocene. The alpine plants could return to the mountains, and under the new stimuli, ancient genera would be revivified and new forms appear. Again the land extended far to the N. S. E. and to some extent to the W. Exchanges would be possible with Australia by transoceanic methods and with the northern palaeotropic floras by either land or across a narrow channel. Towards the end of the period of elevation, when the mountains were at their highest, came the great extension of the glaciers. Then would the palaeotropic element be driven northwards and perhaps eastwards, especially if as is more than probable, the glacial advance was, in part, the result of a colder climate. East of the Southern Alps there would be a steppe-climate on the plateau. Then, by epharmonic change, would arise the intense xerophytes[1]), descendants of mesophytes it may be, such as *Carmichaelia Petriei* from a leafy forest-species, or *Sophora prostrata* from *S. microphylla*. Then, too, would appear that semi-stable xeromorphy seen in the palaeotropic *Hoheria* and *Pennantia*.

Towards the end of the Pleistocene, depression set in once more; the glaciers retreated far into the mountains and the re-peopling of the glaciated

1) This view was first put forth by L. DIELS (1896: 297—98), who, from a searching examination of the anatomical structure of many New Zealand plants, concluded with rare insight, that their xerophily was not in harmony with present day New Zealand conditions and must referred to an ancient steppe-climate.

land, as already described, began. Once more the descendants of the ancient species, some perhaps themselves of high antiquity, commenced to make new forms, acted on by the novel and diverse environments and probably by secular changes of climate first wet, then drier. Then would *Celmisia*, *Veronica*, *Epilobium* and many other genera, no longer held in check by uniform conditions, burst forth into that multiplicity of forms, some reversions, but others epharmonic changes in accordance with their diverse stations. Even yet the species-making is in progress.

The land having receded beyond its present limits, elevation once more took place, and the New Zealand of to-day came into being, peopled by its heterogeneous gathering of plants, children of north and south and east and of the New Zealand soil itself, moulded by great earth-movements and climates of extreme variety.[1]) In one thing they differed from the plants of other regions; no grazing mammals had ever been present to molest them, they possessed no structures that could claim to be defensive.

Finally came man; first the Maori, or it may be his predecessor, but their influence on the vegetation was but slight. Then arrived the European. It is rather more than 100 years since he began to occupy the land, but how great the change his operations have wrought, has been already told. We, who now live in this wonderful country, and love its marvellous vegetation, have set aside sanctuary after sanctuary where the palaeotropic, subantarctic, Australian and palaeozelandic plants, the survivors of that bitter strife with Nature, that commenced millions of years ago, can still pursue their destinies unmolested by their human enemies and the horde of foreign plants and animals he has let loose.

Will our descendants prize this unique heritage from the dim past and preserve these sanctuaries intact?

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1) Nothing shows more clearly how greatly climate must have changed in the temperate Southern Hemisphere than do the angiospermous fossils of Seymour Island and the Antarctic coal discovered by SHACKELTON's expedition. A considerable rise in temperature, accompanied by depression of the land, would undoubtedly be detrimental to the well-being of alpine plants, but, as seen from their present distribution in New Zealand, many thrive under warm lowland conditions, so that a fair number could probably tolerate a considerable rise in temperature. The fossil plants mentioned above clearly show that Antarctica possessed a Tertiary flora distinguished by a small but most characteristic New Zealand element, as evidenced by the following species: *Laurelia insularis, Knightia Andreae, Drimys antarctica* and two species of *Nothofagus*. With these species in one's mind it is easy to agree with SKOTTSBERG that "the Antarctic Continent may have been a centre of evolution from which animals and plants wandered north".

Appendix.

1. Page 31. Soils.

Since the brief account of the soils was written, through the investigations of ASTON, a good deal is now known regarding their chemical composition. From the published results of the above investigator, together with some other soil analyses, WILD, in "Soils and Manures in New Zealand" (1919), has compiled a useful summary.

A distinction must be drawn between soils originating from greywacke and those from mica-schist. The latter are especially fertile and contain, when apparently dry, a considerable amount of available moisture. They occupy a wide area in the North and South Otago botanical districts.

There are many areas of soil derived from limestone in most of the mainland botanical districts, but the fact of a soil overlying limestone by no means proves that it is truly calcareous.

2. Pages 73—74. Dune vegetation.

The dune *Geranium* is not, as stated, p. 76, *G. sessiliflorum* var. *glabrum*, but a more robust plant which is apparently confined to dunes, or their immediate neighbourhood.

On certain dunes in the south of Wellington, (Lyall Bay &c.), *Acaena novae-zelandiae* var. *pallida* is a striking feature. It forms pale, yellowish-green mats on the sand, 1 sq.m, or more, in size and behaves like a true "sand-binder", in its extremely stout, more or less woody stems greatly lengthening when buried by drifting sand. Floristically, this plant bears a much greater resemblance to some of the Australian varieties of *A. Sanguisorbae* than it does to any of its New Zealand allies.

3. Page 83, footnote 1). Senecio rotundifolius.

Judging from specimens collected by ASTON at West Wanganui Inlet (North-western district) it seems clear that the *Senecio* is neither *S. rotundifolius* nor typical *S. elaeagnifolius*, though it is much nearer to the latter. *Senecio rotundifolius*, then is apparently confined, as was always supposed, to the Fiord, South Otago and Stewart botanical districts.

4. Page 95. Families confined to the lowlands and lower hills.

The following, notwithstanding some of their genera being coastal, must be added to the list: *Piperaceae*, *Sapindaceae*, *Verbenaceae* and perhaps *Proteaceae*.

5. Page 111. Biology of lowland trees.

From the far-extending, partially buried roots of *Laurelia novae-zelandiae*, "knees", or solid upright projections, which are probably pneumatophores, rise up out of the shallow water, or muddy soil. Much smaller, cylindrical root-branches, also presumably pneumatophores, have recently (1920) been described by CHEESEMAN for *Eugenia maire*. Apparently, from what I have seen of these organs, they show every transition from ordinary roots, which enter the ground, to those described by the above botanist as erect; those horizontal in direction are a common feature.

6. Page 127. *Hymenophyllaceae* of rain-forest.

Besides the *Hymenophyllaceae* mentioned in the descriptions of various classes of forest the following are usually abundant: *Hymenophyllum flabellatum* (epiphytic), *H. tunbridgense*, *H. bivalve*, and *Trichomanes venosum* (epiphytic on trunks of tree-ferns). *H. pulcherrimum* (tufted epiphyte) is fairly common in montane and lower subalpine forests in the Central Province, but it is particularly plentiful in the south and west of the South Island.

7. Page 137. The forest of Banks Peninsula.

The suggested explanation of the presence of *Podocarpus totara* forest on Banks Peninsula, and of the scanty representation of *Dacrydium cupressinum* and species of *Nothofagus*, is not clearly expressed. What is meant is this: that (1) the primitive forest of Banks Peninsula was *Nothofagus*; that (2), during a wet post-glacial period that genus was almost replaced by *Dacrydium cupressinum*; and that (3), during the subsequent drier cycle — a climate however not dry enough to give the supremacy to *Nothofagus* — *Podocarpus totara* replaced *D. cupressinum*, but did not interfere with *Nothofagus*.

8. Page 148, fig. 38.

This figure belongs to Section III, p. 179, where the relation of the wind-factor to forest and tussock-steppe is briefly indicated.

9. Page 150. Species of gumlands' heath.

Leptospermum heath is the especial habitat for certain terrestrial orchids. The gumlands' heath in the north of the North Auckland botanical district is particularly rich in such plants as the following list shows: *Thelymitra ixioides*, *T. longifolia*, *T. intermedia*, *T. pulchella*, *T. imberbis*, *T. Matthewsii*, *Orthoceras strictum*, *Microtis uniflora*, *Prasophyllum Colensoi*, or an allied form not yet described, *P. pumilum*, *Caleana minor* (rare), *Pterostylis trullifolia*, *P. barbata*, *Caladenia minor*, *C. exigua*, *Chiloglottis cornuta*, and *C. formicifera* (rare).

10. Page 153. Fern-heath.

There is a belt of fern-heath in many places on the lower slopes of the mountains surrounding Lakes Wanaka and Wakatipu. Judging from the relation between this association and forest, it seems not unlikely that the fern-heath denotes the former presence of forest which retreated urther west during a comparatively dry cycle of years. Eastwards, as drier conditions increase, the fern-heath gives place to tussock-grassland (now depleted).

11. Page 156. Phormium swamp.

In a swamp several kilometres from Porirua Harbour (Western Wellington) there is an isolated piece of a much older association of a coastal stamp, evidently dating from a time when the ground would be exposed to brackish water. This is clearly demonstrated by the dominance of *Leptocarpus simplex*. The association stands out most distinctly from the *Phormium* which encloses it. There is abundance of *Cotula asiatica*; stunted *Blechnum capense* about half the height of the *Leptocarpus* is plentiful; *Euphrasia cuneata*, dotted here and there, is an unexpected member; finally, there is stunted *Phormium* less than 30 cm. high.

12. Page 168. Low tussock-steppe.

The respective dominance of *Festuca novae-zelandiae* or *Poa caespitosa* depends upon the water-content of the soil, the first-named grass tolerating the driest conditions. According to the character of the climate, or the soil, both grasses may be present in about equal quantity, one or the other may dominate, or either may be the sole tussock. But present distribution, owing to sheep-grazing and fire, is no criterion as to the composition of the primitive association.

13. Page 174. Vertical distribution.

Glaciers descending to a low altitude bring about conditions favouring the presence of high-mountain species. This can be readily observed in the Hooker Valley and near the Franz Josef glacier. There is, thus, not only the snow-line, but the ice-line to be considered.

14. Page 202. Discaria toumatou.

A few weeks ago Professor J. PARK made the important discovery of two adult flowering bushes of *Discaria toumatou*, semi-juvenile in form. The twigs are slender, drooping, and not stiff, the spines are more or less soft and the flowers comparatively few. The plant might well be considered as a form growing under conditions of especial shade and moisture in the air, yet the two bushes are side by side with the usual intense xerophytic form of the species.

15. Page 213. Discaria-steppe.

Besides the species mentioned in the footnote, the North Otago *Discaria* association also includes the small tree, *Olearia lineata*. At the present time much *Discaria* scrub in gullies is invaded by the introduced *Rosa eglanteria* and *Sambucus nigra*.

16. Page 216. Veronica scrub.

In certain localities *Veronica cupressoides* is a characteristic plant.

17. Page 219. Cassinia scrub.

Much *Cassinia* scrub at the present time is an indigenous-induced association, its presence a sign of burning the tussock-grassland. Where more than one species of *Cassinia* is present there is a polymorphic collection of individuals impossible to classify in the present state of knowledge.

18. Page 224. Rock associations of the dry mountains.

The following species, some limited in their distribution, may be added to the species already given: *Trisetum subspicatum*, *T. Cheesemanii*, *Luzula pumila*, *L. campestris* (one or other of the vars.), *Griselinia littoralis*, *Corokia Cotoneaster*, *Anisotome aromatica* var., *Pimelea aridula*, *Coprosma cuneata*, *Epilobium pubens*, *Veronica Traversii*, *Olearia cymbifolia*, *Helichrysum pauciflorum* (obligate rock-plant), *H. depressum*, *H. glomeratum*, *Senecio Haastii*. Where *H. glomeratum* and *H. bellidioides* occur in proximity, the hybrid *H. Purdiei* — until its discovery in the mountains by CHRISTENSEN a few years ago supposed to be a coastal plant of most restricted distribution — will usually be present.

19. Page 225. Rock vegetation of the wet mountains.

On the range traversed by the Motueka-Takaka road at an altitude of about 900 m there is a rock association living under strong xerophytic conditions notwithstanding the wet climate. The substratum consists of irregular masses of hard limestone, the general aspect being that of a rock-garden planted with low shrubs, the white stones showing in abundance. Water never lies on the surface, but at once escapes through holes in the rock and is carried away by underground drainage.

There is an open association of shrubs, most more or less prostrate, even the dense, divaricating *Corokia Cotoneaster* having taken on that habit. The following are some of the species: *Asplenium Trichomanes* (in crevices), *Astelia montana*, *Nothofagus cliffortioides*, *Pittosporum divaricatum*, *Pimelea longifolia* (erect), *Cardamine heterophylla* var., *Corokia Cotoneaster*, *Suttonia divaricata*, *Veronica Menziesii*, *V.* sp. with glaucous leaves, *Cassinia Vauvilliersii* (where there is a little soil and moister conditions) and *Gnaphalium Traversii*.

20. Page 231. Low tussock steppe.

A more correct name would be *Festuca* tussock-grassland, since *F. novae-zelandiae* is easily dominant, *Poa caespitosa* being wanting over wide areas, or confined to the moister ground. Probably in the primitive formation *Agropyron scabrum* and *Dichelachne crinita* would be present as tussocks, whereas now they occur only as slender, straggling plants in the actual fescue or poa tussocks.

21. Page 235. Mineral Belt.

As no description is given in the text of the remarkable vegetation of the Mineral Belt of Nelson and Marlborough a brief account seems necessary.

The belt is a narrow, stony tract, consisting of peridotite and serpentine rocks, extending for about 96 km from D'Urville Island to Nelson with its widest part (about 5 km) in the vicinity of the Dun mountain. The vegetation of the belt both in its density, its associations and its growth-forms presents a striking contrast to that of the adjacent luxuriant *Nothofagus* forest. The transition from forest to Mineral belt vegetation is hardly to be seen, each standing out distinct. Not only does the Magnesian soil influence the associations but it changes the growth-forms, so that trees beyond its influence are merely shrubs on the belt (the spp. of *Nothofagus*, *Griselinia littoralis*). The associations of the belt consist of shrubland, fell-field and tall tussock-grassland, the latter with a small variety of *Danthonia flavescens* dominant. Taking the species of shrubland and fell-field together, for these associations merge into one another, the following are the more important: *Phyllocladus alpinus*, *Poa* sp. (related to *P. acicularifolia*), *Festuca* sp. (unnamed), *Phormium Colensoi* (*Cookianum*), *Astelia montana* var., *Thelymitra longifolia*, *Libertia ixioides* var., *Exocarpus Bidwillii*, *Nothofagus fusca*, *N. cliffortioides*, *Muehlenbeckia axillaris*, *Colobanthus quitensis*, *Claytonia australasica*, *Notothlaspi australis*, *Pittosporum divaricatum*, *Hymenanthera dentata* var. *alpina*, *Pimelea Suteri*, *Leptospermum scoparium*, *Anisotome aromatica*, *A. filifolia*, *Griselinia littoralis*, *Dracophyllum rosmarinifolium*, *Styphelia acerosa*, *Suttonia divaricata*, *Myosotis Monroi*, *Veronica buxifolia* var., *Coprosma propinqua*, *C. foetidissima*, *C. Cunninghamii* (or an undescribed species), *Helichrysum bellidioides*, *Cassinia albida* var., *Olearia virgata* var.

22. Page 240. Fell-field.

A characteristic plant of large stony débris at above 1200 m altitude is the summergreen fern, *Polystichum cystostegia*.

23. Page 256. Rainfall of Chatam Island.

The mean rainfall of Chatam Island for a period of 24 years (accidentally omitted on p. 43) is, according to D. C. BATES, 97 cm. The greatest annual rainfall was 123 cm in 1904 and the lowest 62 cm in 1897.

24. Page 289. Depleted Central Otago.

Other indigenous species holding their own on the depleted area of Central Otago are: *Poa Lindsayi*, *Danthonia Buchanani* (but cropped closely by sheep and rabbits), *Urtica aspera* (where there are large stones), *Claytonia australasica* (on shady slopes), *Oxalis corniculata*, *Hypericum gramineum* and *Epilobium Hectori*.

There is an interesting vernal association of annuals composed mainly of introduced species; the following are the principal: *Bromus hordeaceus*, *B. sterilis*, *Hordeum murinum*, *Festuca myuros*, *Urtica urens*, *Cerastium triviale*, *Myosurus aristatus* (indigenous), *Ranunculus falcatus*, *Erophila verna*, *Erodium Cicutarium*, *Anagallis arvensis*, *Myosotis arvensis*, and *M. pygmaea* (indigenous).

25. Page 291. Indigenous-induced associations.

An interesting example of the increase of an indigenous plant is afforded by the behaviour of *Lepidium obtusatum.* This is an exceedingly rare species, as it occurs only in two localities in each of which its area of occupation is small. Near the western entrance to Wellington Harbour it occurred on the cliffs. But recent removal of stone from these had led to artificial talus slopes, and there the plant is spreading rapidly by means of underground stems. In appearance *L. obtusatum* represents, even when in flower, a huge crusty saxifrage. Its leaves arranged in rosettes are very thick, glossy and rather dark green. The other members of the indigenous-introduced talus association are *Mesembryanthemum australe* and *Raoulia australis.*

26. Page 327. The Mesozoic flora.

The Mesozoic flora as determined by ARBER, (The Earlier Mesozoic Floras of New Zealand, Wellington, 1917), comprised 48 species classified as follows: *Equisetales* 2 species, Fern-like Plants 27 species, *Cycadophyta* 6 species, *Podozamiteae* 1 species, *Ginkgoales* 1 species, *Coniferales 8*, *Angiospermae* (Dicotyledones) 2 species, Incertae Sedis 1 species.

With regard to Mesozoic land-connections the opinion is expressed that such may have existed between Antarctica, New Zealand and Australia, but that South Africa was not united either to Antarctica or Australia.

27. Page 328. Glacial Period.

It appears not improbable that the New Zealand glacial period may have been much more recent than indicated in this book.

Corrections.

Orthographical errors which cannot mislead the reader are not included here.

Page 5 line 2 from top for Islands read Island.
» 5 » 4 » » » esem read seem.
» 6 » 7 » bottom for the volume read this volume.
» 8 » 9 » » » Moehau read Moehu.
» 22 » 6 » top for 104,581 read 271,910.
» 22 » 13 » » » 44,468 » 115,616.
» 22 » 14 » » » 58,525 » 152,165.
» 26 » 9 » » » 200 read 120 and for 10 read 16.
» 28 » 14 » bottom for 6 read 0.6.
» 28 » 7 » » » 869 read 900.
» 34 » 17 » » » district read distinct.
» 72 » 17 » » » Sounds read Fiord.
» 73 » 1 » top for *linearis* read *lineata.*
» 81 » 17 » » » shale read marl.
» 89 » 6 » » » *lucida* » *robusta.*
» 89 » 5 » bottom for *Raoulia* read *Rubus.*
» 96 » 13 » top for *Nothospartium* read *Notospartium.*
» 103 » 2 » » » Whiky read Whitey.
» 118 » 3 footnote 2) for *L. flavidus* read *E. flavida.*
» 125 » 3 from bottom for *Rhapolostylis* read *Rhopalostylis.*
» 130 » 12 » » » *adiantiforme* read *adiantoides.*
» 144 bottom line for Sounds read Cook.
» 161 line 1 footnote 2) for shrub-heath read heath-moor.
» 163 » 3 from bottom for *Sarothamnus* read *Cytisus.*
» 168 » 21 » top for *D.* read *Microlaena.*
» 170 » 14 » bottom for shale read marl.
» 171 » 12 » top for *semi-annularis* read *semiannularis.*
» 172 » 12,13 » » » *angustifolia* read *dentata.*
» 173 » 6 » » » 45 read 47.
» 173 » 12 » » » delete and one family.
» 173 » 14 » » » delete *Loganiaceae.*
» 174 » 10 » » » 422 read 423.
» 175 » 17 » » » 320 read 318.
» 177 » 2 » » » alter *autumnale* to *autumnalis.*
» 182 » 3 footnote 1) for 13 read 10 for 18 read 20 and delete New Zealand and.
» 182 » 4 footnote 1) for 9 read 12.
» 192 » 9 from top for 17 read 18.
» 195 » 7 » » delete; after 56.
» 195 » 13 » » for 12 read 11.
» 195 » 16 » » » 54 » 64.
» 195 » 17 » » » 61 » 81.
» 208 » 6 » bottom alter *Drimys Traversii* to *Dracophyllum Traversii.*
» 208 » 16 » top alter F. G. to F. J.

Index of Plant Names.

In this Index nmaes not accurately recorded in the body of the work are corrected and a few observations made regarding certain other names.

22*

Druck von Breitkopf & Härtel in Leipzig.

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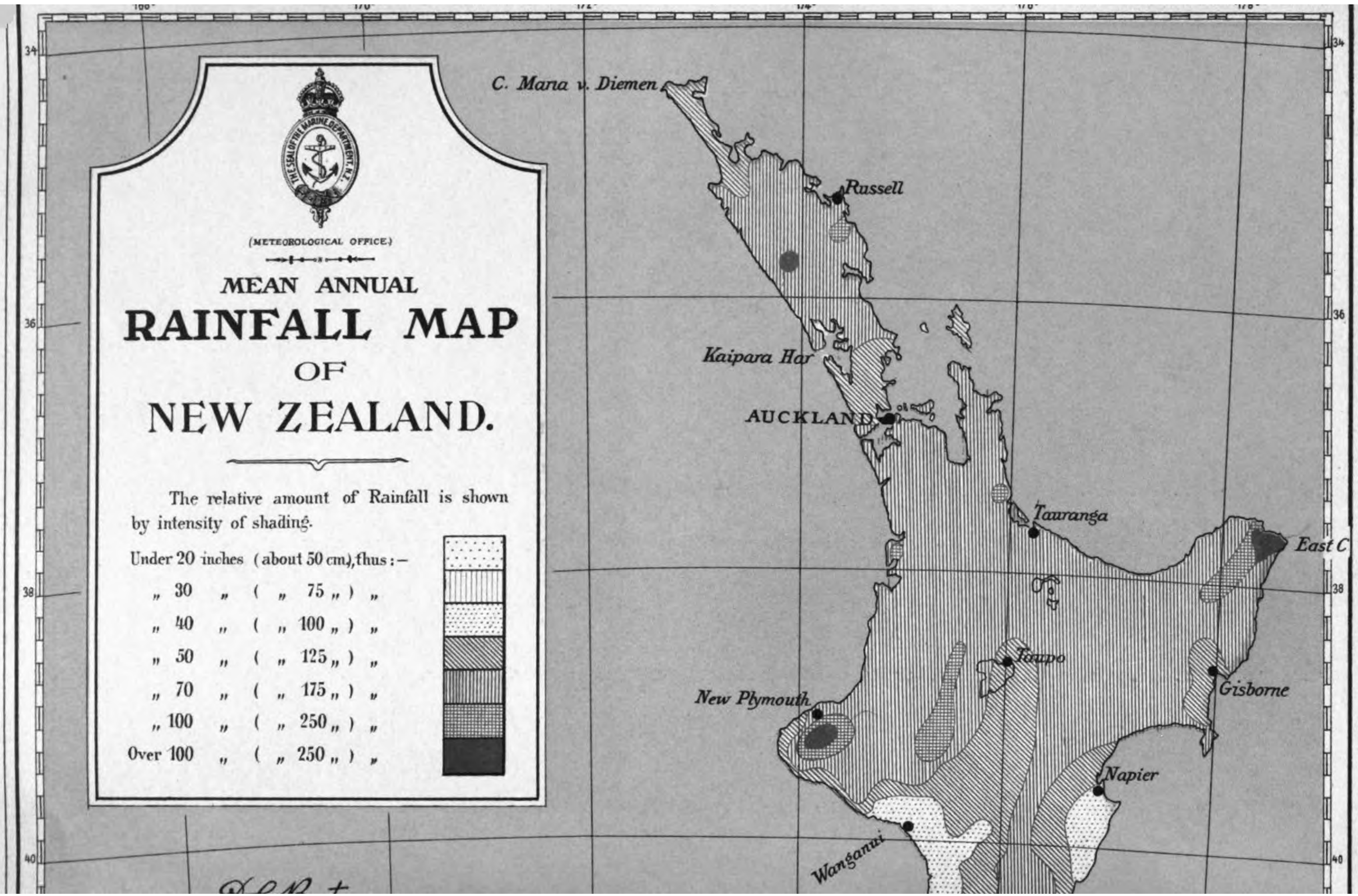
(METEOROLOGICAL OFFICE.)
MEAN ANNUAL
RAINFALL MAP
OF
NEW ZEALAND.
The relative amount of Rainfall is shown by intensity of shading.
Under 20 inches (about 50 cm), thus :–
„ 30 „ („ 75 „) „
„ 40 „ („ 100 „) „
„ 50 „ („ 125 „) „
„ 70 „ („ 175 „) „
„ 100 „ („ 250 „) „
Over 100 „ („ 250 „) „
C. Maria v. Diemen
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New Plymouth
Napier
Wanganui
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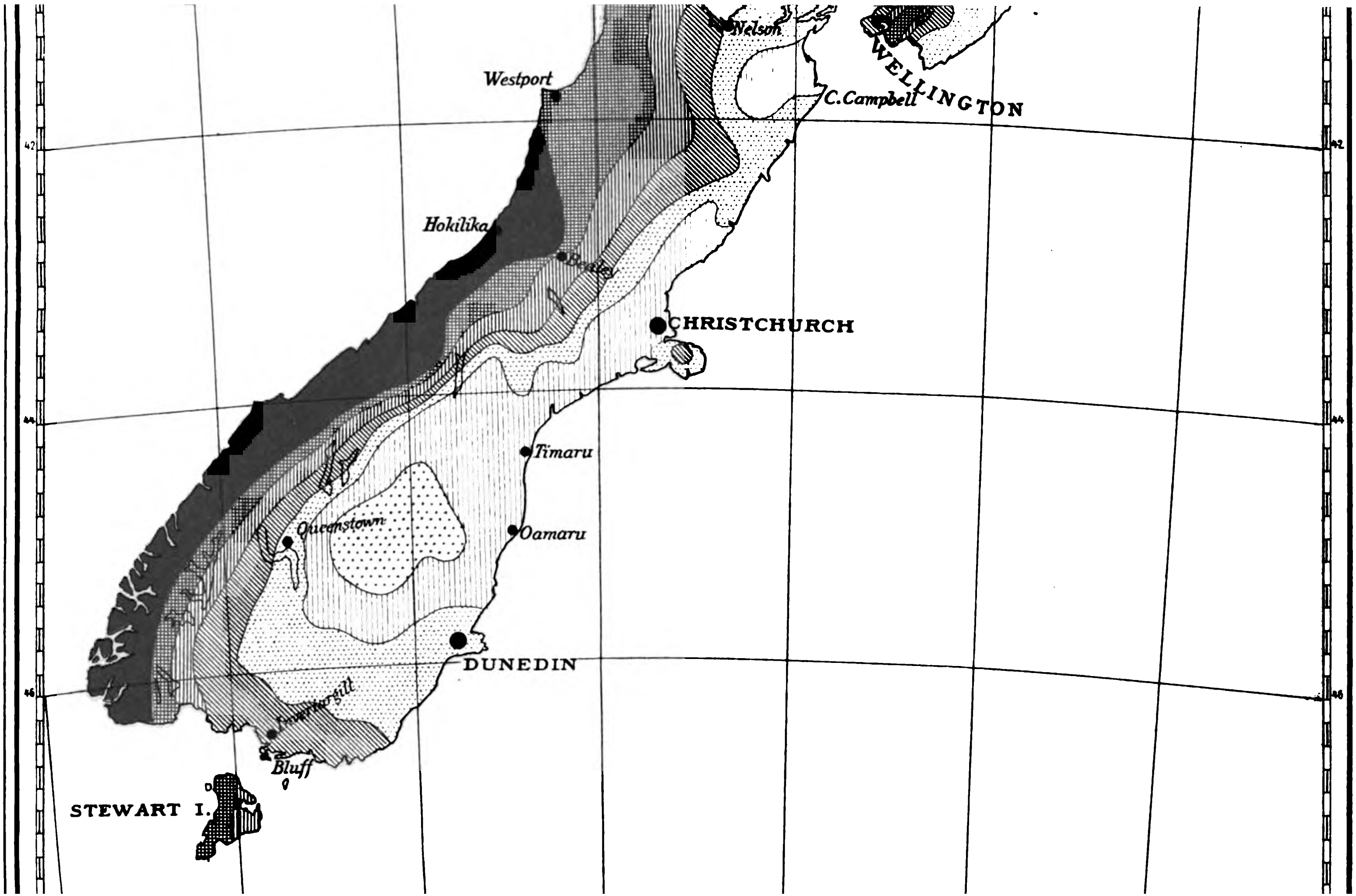

Nelson
WELLINGTON
C. Campbell
Westport
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Hokitika
CHRISTCHURCH
44
Timaru
Queenstown
Oamaru
DUNEDIN
46
Invercargill
Bluff
STEWART I.

Fig. 3. Stilbocarpa Lyallii growing among rocks, Ruapuke Island. Inflorescence dimly seen hidden by leaves in foreground.
Photo., L. Cockayne.


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Fig. 5. Mangrove swamp showing one adult tree, pneumatophores and young plants of **Avicennia officinalis.**
Photo., L. Cockayne.

Fig. 6. Natural **Spinifex hirsutus** foredune. W. Coast of Ruahine—Cook district
Photo., L. Cockayne.

Fig. 7. Active dune getting clothed by **Phormium tenax, Arundo conspicua** and **Cassinia leptophylla.** Ruahine — Cook district on W.
Photo., L. Cockayne.

:e VI, to pages 77, 78.

low. In foreground

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Lyall Bay, Ruahine —

Fig. 11. Sand-worn stones where dunes are blown away. Here and th
Coprosma acerosa. Egmont-Wanganui dis rict.
Photo., L. Cockayne.

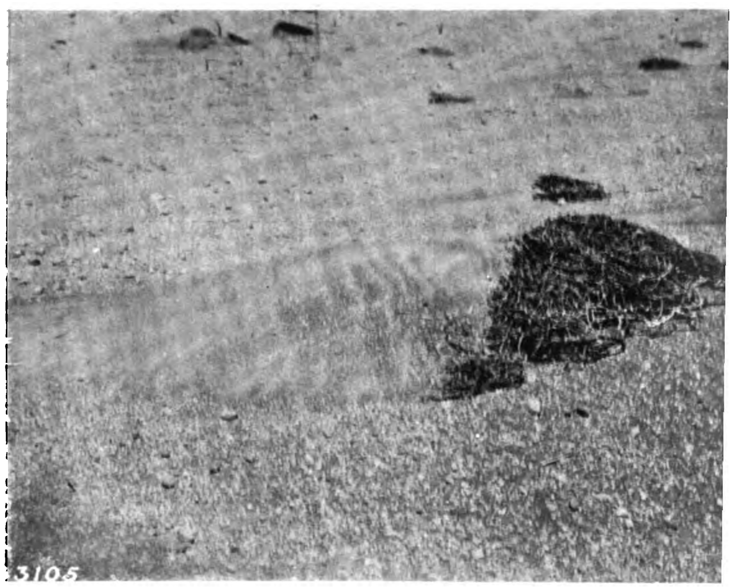
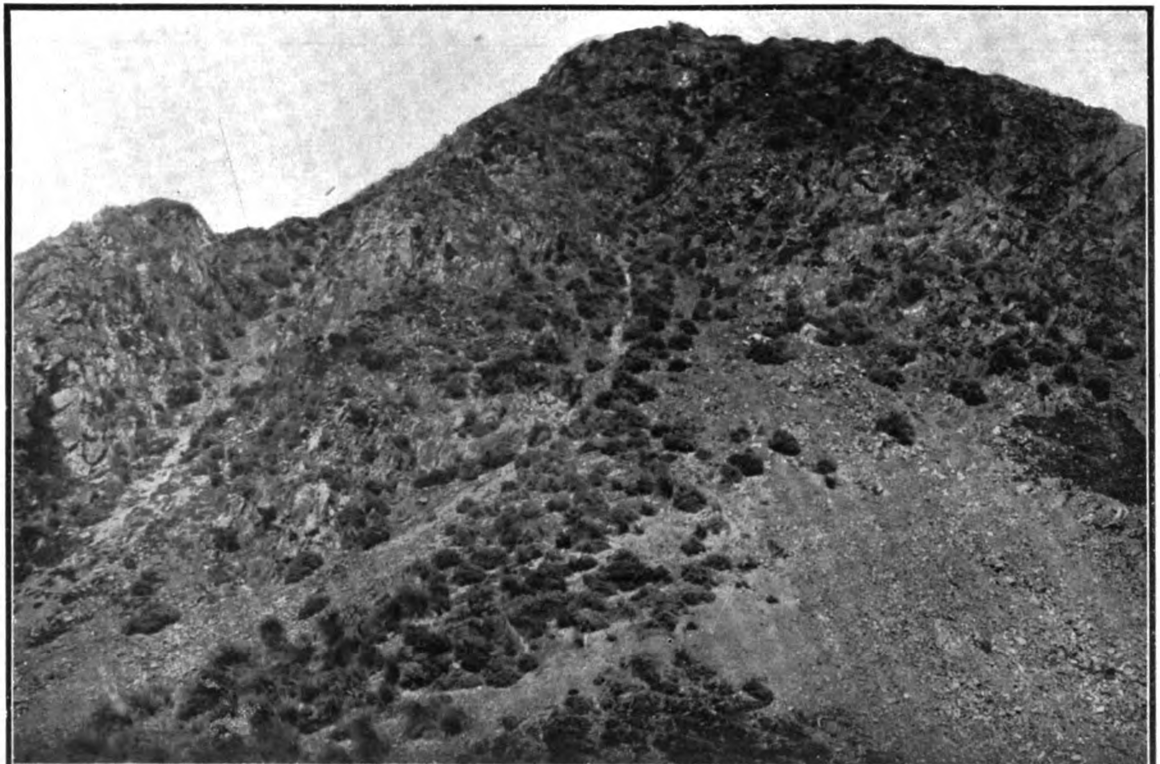


Fig. 12. Tongue of sand in lee of **Coprosma acerosa.** Sand-hills b
away. Egmont-Wanganui district.
Photo., L. Cockayne.

Fig. 13. Mat of **Celmisia Lindsayi** growing on coastal cliff. Nugget Point, South Otago district.
Photo., L. Cockayne.



showing density of foliage.
Photo., L. Cockayne.

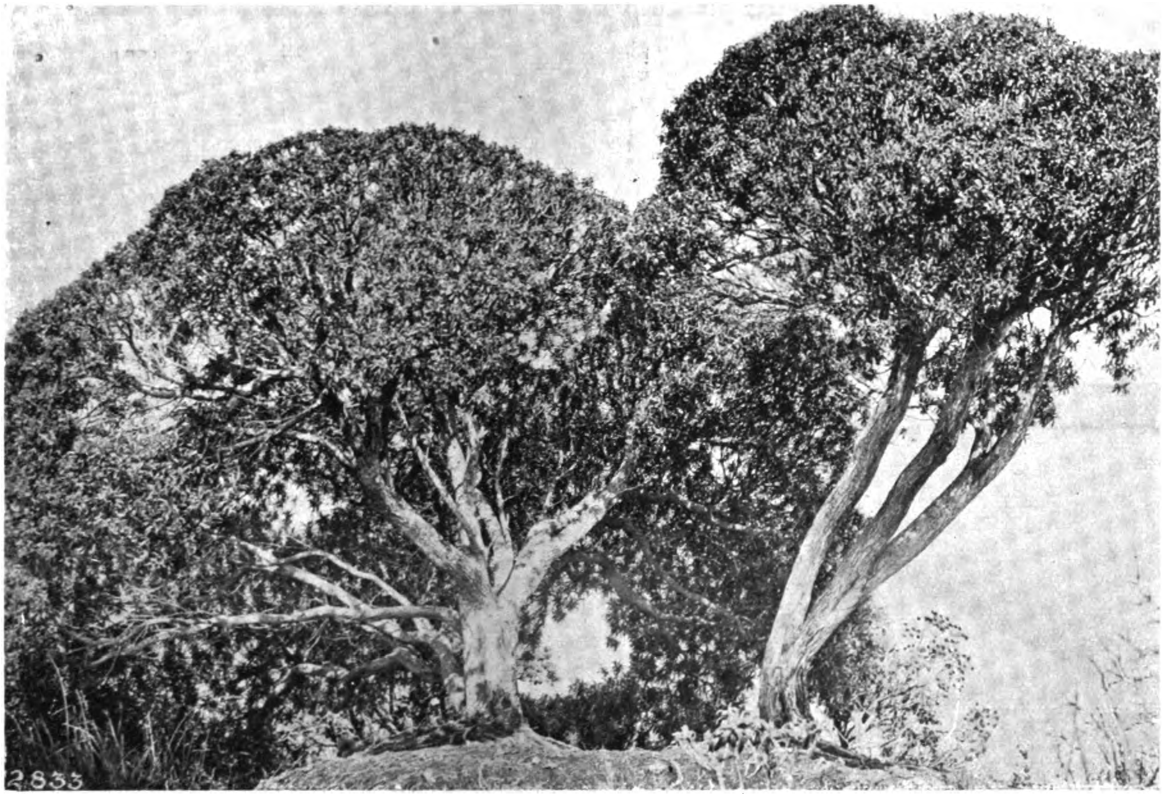


Fig. 16. Isolated trees of **Olearia angustifolia,** Coast of Stewart Island. The tree on the left is about 3 m high; its trunk is 27.5 cm in diam. and the rounded crown 12 m through.

Fig. 17. View on Rangitoto Island, North Auckland district. **Griselinia lucida** in centre.
Photo., L. Cockayne.

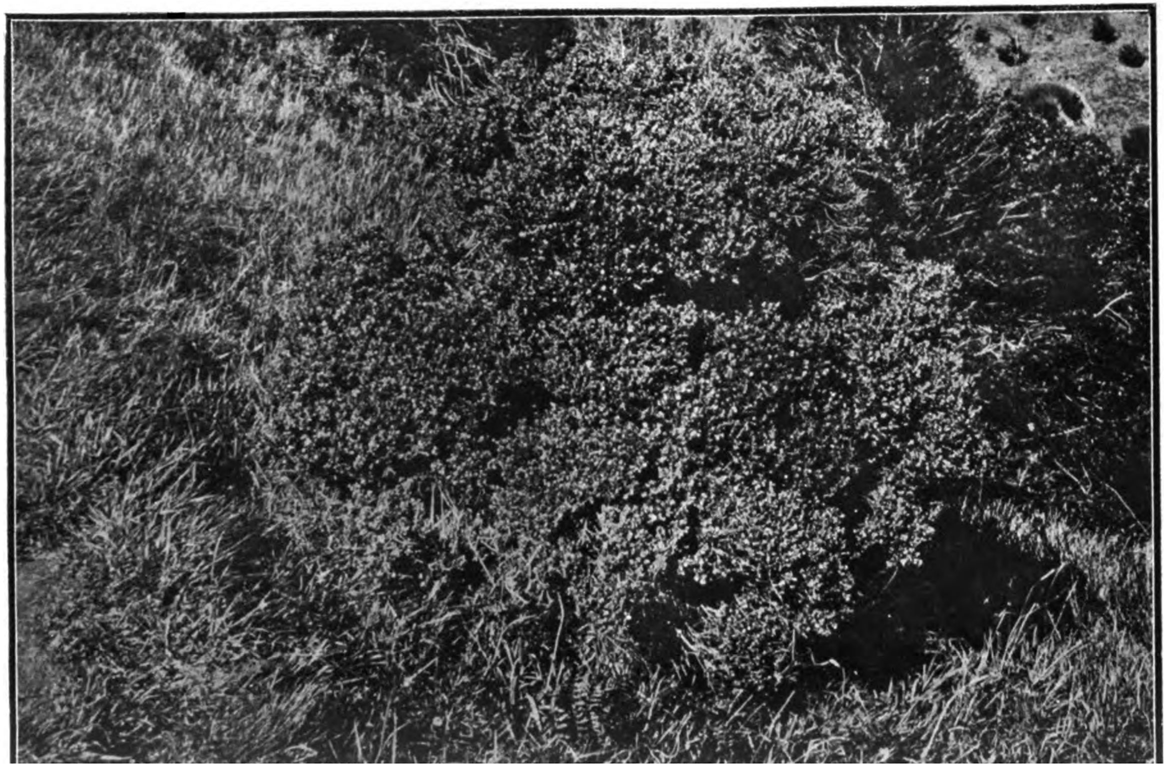
Fig. 19. Belt of **Metrosideros tomentosa** along shore near Mongonui, North Auckland district.
Photo., L. Cockayne.

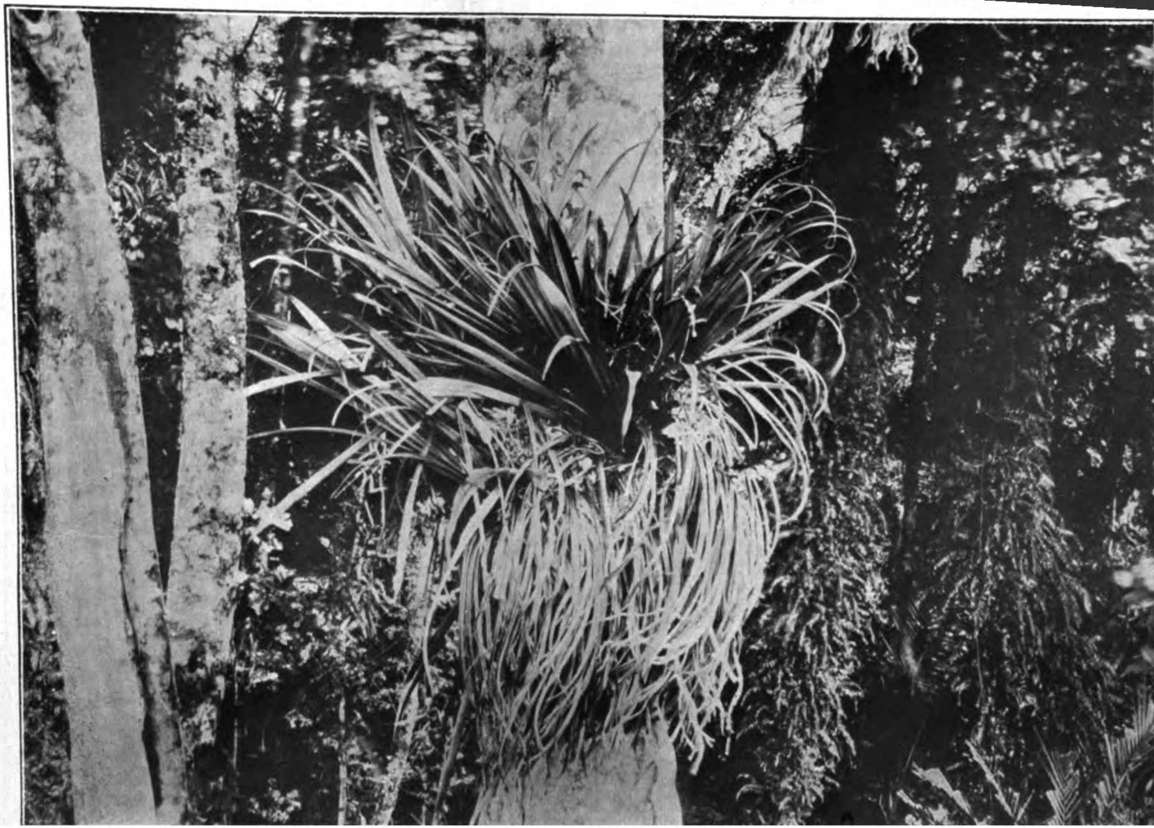
Fig. 20. Interior of forest: trunks of rimu (**Dacrydium cupressinum**) in centre.

Fig. 21. Base of **Metrosideros robusta** showing its irregular habit.
Photo., L. Cockayne.

Fig. 22. Base of "trunk" of **Weinmannia racemosa** formed out of roots. Forest of Stewart Island.

Plate XIX, to page 116.





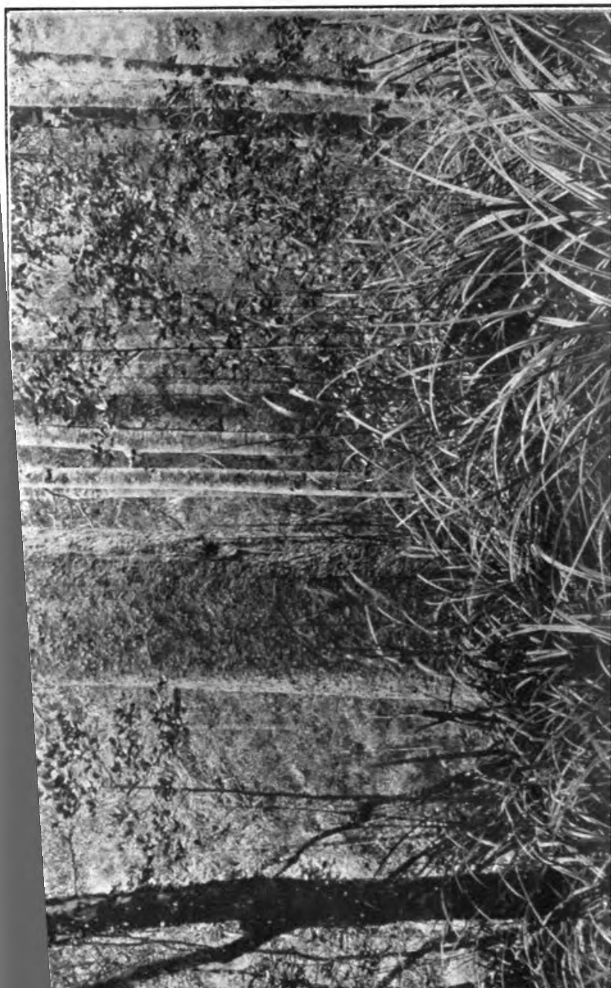


Fig. 31. Interior of Open Kauri-forest, showing the slender Taraire Trunks and Kauris to right and left in background.
Photo., L. Cockayne.

Fig. 33. Interior of Waipoua Kauri forest. The large trees are Kauris.
Photo., L. Cockayne.

Fig. 39. **Pomaderris Edgerleyi** as member of Gumlands' Heath on the North Cape promontory, North Auckland district.
Photo., L. Cockayne.

Fig. 40. Stony river-bed association; Western bot. district, Otira Valley at 300 m alt.; **Raoulia tenuicaulis**; juvenile form right-hand corner.
Photo., L. Cockayne.

Fig. 41. Low forest of river-be
(low tree), on right **Sutton**

Fig. 42. Low forest of
crassifolium sho

Fig. 43. **Helichrysum Sinclairii** growing on dry rock, lower subalpine-belt. Awatere Valley, North-eastern district. Photo., L. Cockayne.

Fig. 44. New vegetation c
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Fig. 45. Interior of Scrul
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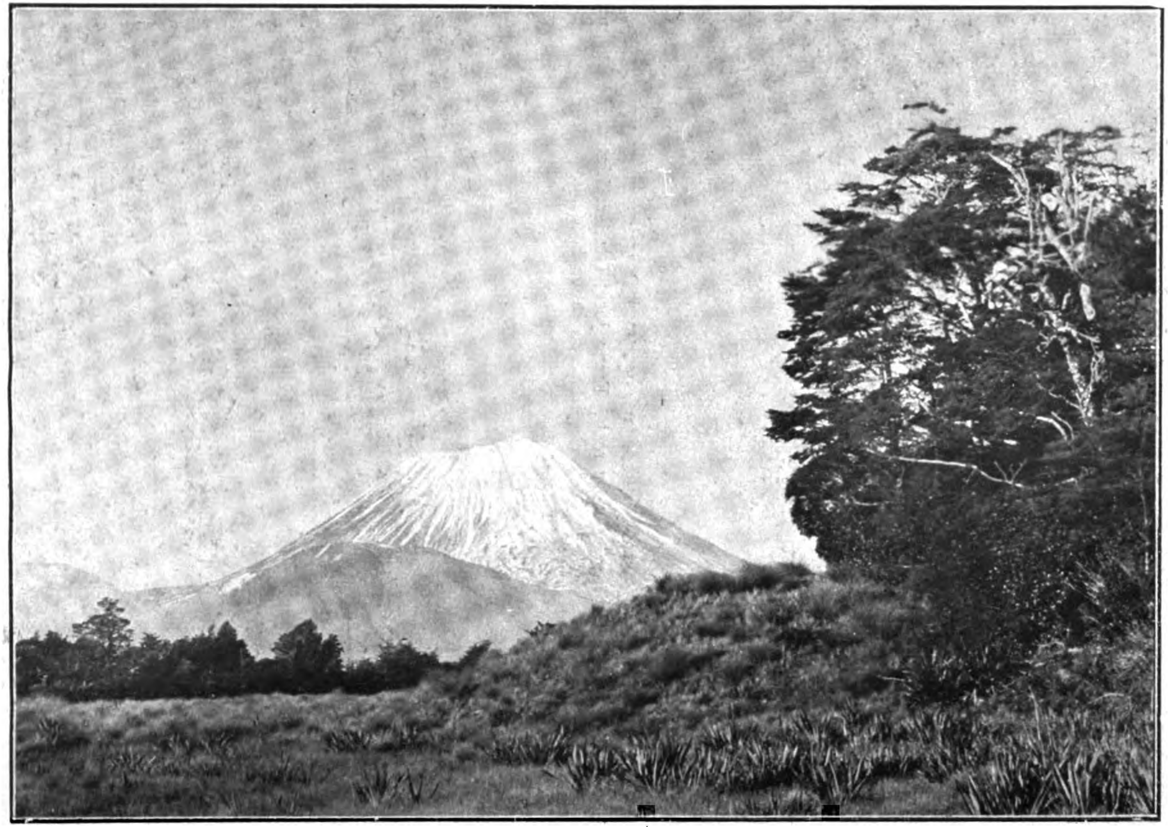

Fig. 46. Ngauruhoe Mountain from near Whakapapa Stream with tall tussock-steppe in foreground and **Nothofagus cliffortioides** on right. Photo., P. Keller.

Fig. 47. Snow av

Fig. 48. Type
subalpine scrub c

Fig. 46. Ngauruhoe Mountain from near Whakapapa Stream with tall tussock-steppe in foreground and **Nothofagus cliffortioides** on right. Photo., P. Keller.

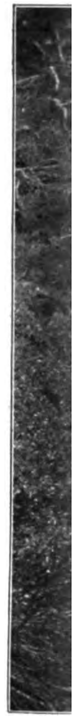

Fig. 4

Fig.
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Fig. 49. Cushion of **Dracophyllum politum,** about 60 cm high, surrounded by low **Olearia Colensoi.** Subalpine-scrub. Mt. Anglem, Stewart Island.

Photo., L. Cockayne.

Fig. 52. Close view cushion of **Phyllachne clavigera.**
Photo., S. Page.

Fig. 55. U

Fig. 56.
dist

Fig. 58. Interior of low forest or scrub, Price's Peak, Stewart Island, near summit. Bryophyte cushions on floor.
Photo., L. Cockayne.

Fig. 59. Horizontal trunk of **Olearia ilicifolia** in subalpine forest (**Podocarpus-Libocedrus**) near source of R. Rakaia, Southern Alps, Western district.
Photo., L. Cockayne.

Fig. 61. **Gentiana bellidifolia** growing on scoria desert, Mt. Tongariro at about 1500 m altitude. Flowers 1.2 cm in diam.
Photo., L. Cockayne.

'ig. 63. Junction of coarse shingle-slip and subalpine-scrub, Mt. Murray near source of R. Rakaia, :. of Western district. **Ranunculus Lyallii** in foreground; centre and back **Veronica subalpina.**

g. 65. Subalpine- scrub of Mt. Greenland, Western district. On extreme left **Quintinia** :**utifolia,** then **Metrosideros lucida** (both trees of forest): in centre **Pittosporum divaricatum,** then on right, **Nothopanax simplex.** Photo., L. Cockayne.

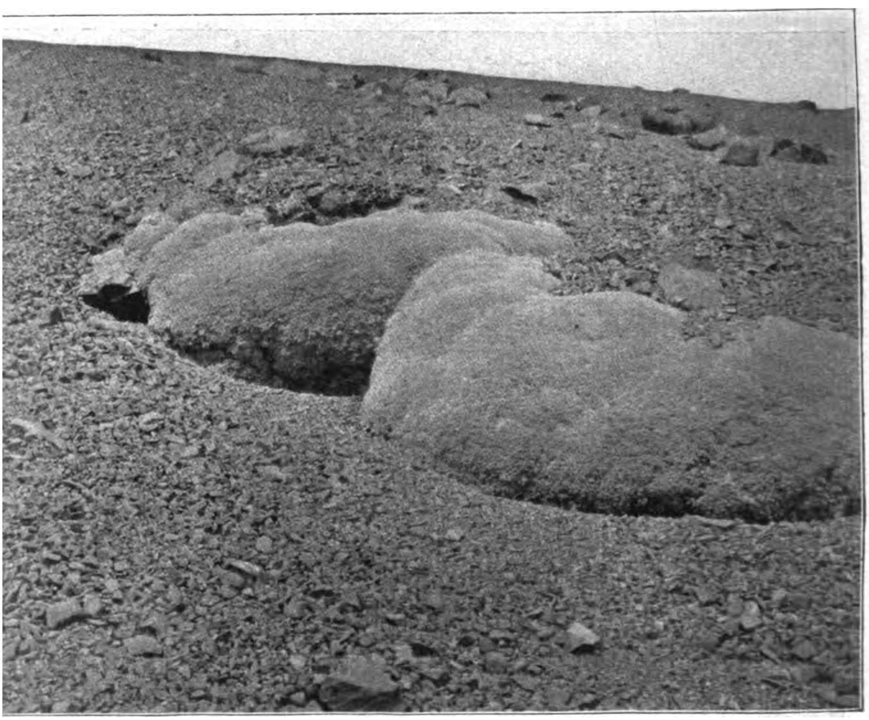
Plate XLV, to page 218.

Fig. 67. Terminal face of lava-flow from the Red Crater to the Central Crater of Tongariro.
Photo., L. Cockayne.

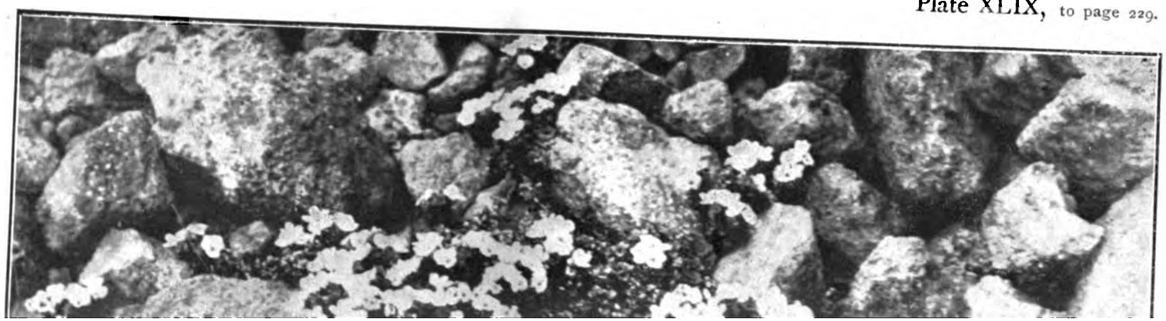
Fig. 68. Vegetation o
grass in c

Fig. 69. **Celmisia Wall**
Baird

Fig. 70. **Notothlaspi rosulatum** growing on shingle slip of river-terrace, Castle Hill, Canterbury, Eastern district, at about 750 m altitude.
Photo., L. Cockayne.



g. 71. **Haastia pulvinaris** growing on coarse débris, Mt. Tarndale at 1500 m altitude.
Photo., L. Cockayne.



. 75. **Raoulia grandiflora.** Fell-field, Mt. Hector, Tararua Mts. (Ruahine-Cook botanical district' at 1440 m alt.
Photo., E. Bruce.

Fig. 76. **Leucogenes Leontopodium**, fell-field, Tararua Mts., Ruahine-Cook district.
Photo., E. Bruce Levy.

Fig. 77. **Celmisia coriacea in**

Fig. 78. Low Tussock-gras
of Cameron

Fig. 79. **Celmisia hieracifolia,** fell-field. Tararua Mts., Ruahine-Cook district.
Photo., E. Bruce Levy.

ɟ. 80. **Pimelea Gnidia in low subalpine-scrub with Phormium Cookianum. Tararua Mts., Ruahine-Cook district.**
Photo., E. Bruce Levy.

Fig. 83. Cushions of **Montia fontana** in shallow running water at about 1200 m altitude on Volcanic Plateau.
Photo., L. Cockayne.

Fig. 84. Colony

Fig. 85. Sand-covered rock vegetation of Chatham Province and district. Left-hand, — **Veronica chathamica;** right hand, — **Sonchus grandifolius.** The grass is **Festuca Coxii.**
Photo., W. R. Oliver.

Fig. 87. Interior of open **Metrosideros lucida** forest, Lord Auckland's Islands, showing habit of the tree.
Photo., S. Page.

Fig. 88. Poa ramosissima
Harbour;

Fig. 89. Interior of **Metrosideros lucida** forest, Lord Auckland's Group, showing tangle of branches. Here the usual dense undergrowth is absent, only a few ferns are present.

Photo., S. Page.

Plate LXI, to page 273.

Fig. 91. In foreground, tussock-moor with **Danthonia antarctica** and in background wind-shorn **Metrosideros lucida.** At about 300 m altitude, Lord **Auckland's Island.**

Photo., S. Page.

Fig. 92. Colony
Gro

ꞔ. 93. **Pleurophyllum criniferum in bloom and bud. Adams Island, Lord Auckland's Group.**

Photo., S. Page.

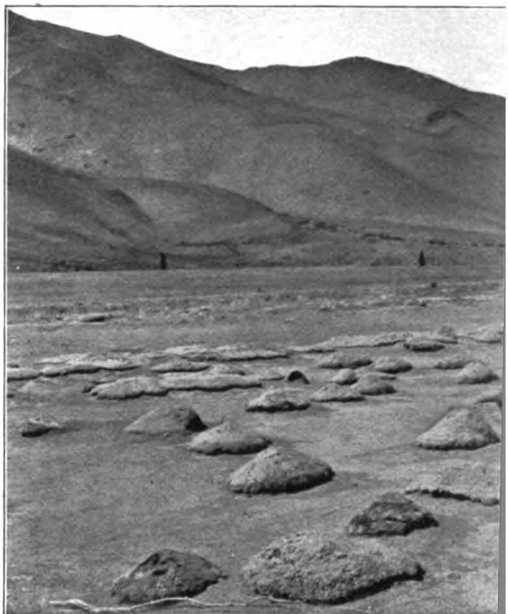


Fig. 94. Replacement of tussock-steppe by cushions c
by drifting sand. Tarras, North Ota
Photo., L. Coc

Fig. 95. Replacement of tussock-steppe destroyed
Raoulia lutescens. Induced-dese
Photo., L. Coc